PLANS FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES

From BULLETIN OF THE BUREAU OF FISHERIES, Volume XXVIII, 1908

Proceedings of the Fourth International Fishery Congress : : Washington, 1908

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By S. W. Downing

Superintendent U. S. Fisheries Station, Put-in Bay, Ohio

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES.

By S. W. DOWNING,
Superintendent U. S. Fisheries Station, Put-in Bay, Ohio.

In discussing this subject it will first be necessary that we understand something of the habits and the manner of reproduction of these fishes, and the probable increase and losses in numbers under natural conditions. Since the same conditions exist and the same reasoning will apply to all the lakes of the chain, we will confine our remarks to the conditions in Lake Erie.

BREEDING HABITS AND NATURAL REPRODUCTIVITY OF WHITEFISH.

The adult whitefishes are migratory, leaving the lower end of the lake and the deeper waters each year as the spawning season approaches and the breeding instinct prompts them, and seeking their natural spawning beds, which consist of the reefs among the islands and the rocky and sandy bottoms of the shoaler portions of the lake. Most of these reefs and shoals are of that peculiar formation called honeycombed rock; that is, instead of being gravelly or smooth these rocks are dotted with holes and small cavities into which the eggs, as they are voided by the fish, may drop and be comparatively safe from being eaten by the suckers and other spawn-eating fishes, water lizards, or other enemies, and also from being covered by mud, silt, and other filth, and smothered, as they would be if deposited on mud bottom.

Were the whitefish nest builders, and did they pair as some of the other fishes do so as to perform the function of fertilizing their eggs with any degree of certainty, the chances for a large production of young under such favorable conditions would be very good, indeed; but they are not nest builders, neither do they mate; on the contrary they approach the spawning grounds singly and in schools, and are what is known as "school spawners," the female extruding her eggs wherever she may happen to be, regardless of whether there is a male fish within close proximity or not. In consequence but very few of the fish come together so as properly to perform the functions of fertilization; and when it is

known, as was demonstrated by Mr. J. J. Stranahan by a very careful experiment in the fall of 1897, that the life of an unfertilized whitefish egg, if left in the water, is less than 4 minutes, while more than 50 per cent of them perish in 1½ minutes, and the life germ contained in the milt of the male fish may be fairly supposed to live no longer under the same conditions, it will readily be seen that the percentage of eggs fertilized under natural conditions must of a necessity be very small. In fact, it is estimated by those fish culturists who have had most to do with the propagation of whitefish that not more than 1 per cent of the eggs are fertilized when deposited under natural conditions. At this rate let us see how many fertile eggs each pair of whitefish will produce each season.

It is estimated that the average number of eggs produced annually by each female whitefish is 35,000. The greatest number the writer has ever known to be secured from one fish was 150,000, from a fish weighing 11 pounds, giving 13,636 eggs to the pound of fish. This would be equivalent to a little more than 37,000 eggs from a fish weighing 2¾ pounds, and as the average weight of the spawning whitefish is from 2½ to 3 pounds it will be seen that 35,000 eggs to the fish should be nearly correct. Then if each pair of whitefish produce 35,000 eggs, and but 1 per cent of them are fertilized, 350 fertile eggs to the pair is all that can be expected to commence with. As the period of incubation for whitefish eggs is from 128 to 150 days, and as these fertile eggs must lie on the lake bottom all this time, in danger of destruction by being smothered in mud and filth as previously shown, and exposed to the still greater danger of being eaten by all kinds of aquatic animals that feed at the lake bottom, it is quite evident that but few of these 350 fertile eggs will survive to reach the fry stage.

It is evident, moreover, that nature never intended there should be such a large increase in numbers as would result from anything like a perfect fertilization, for in that case the lake in a short time would be so densely inhabited that the waters could not produce sufficient food for all; neither would there be room in the lake for them if they came to maturity. It is therefore safe to suppose that naturally the number increases but little if it more than overbalances the loss, and reasoning from the known to the unknown we are sure that this is true.

The number of young produced each year by those fishes, of which there is a large family, that carry their young through the period of incubation and produce them alive, ranges, so far as the writer has been able to learn, from 1 to 22, giving an average of 11 young to each pair of fish; and as these fishes are very numerous where found, it appears that this rate of increase in the fry state is sufficient to more than overcome the losses under natural conditions. Thus by analogy we have the proof that an increase of 11 young from each pair of fish of any kind, including whitefish, is more than enough to overbalance the natural losses.

WORK OF THE HATCHERIES.

But the whitefish, on account of being such an excellent food fish, is more sought after than many others and is taken by every device that man has been able to invent and in the greatest numbers possible on all occasions, so that the natural losses are many times multiplied by this take of fish which may justly be termed "artificial" losses. If this artificial loss is continued, then in order that the loss shall not greatly overbalance the natural increase there must of necessity be introduced an artificial increase. Happily this can be accomplished, in fact is being accomplished, in several places by the aid of the hatcheries. The method employed is to have men go out with the commercial fishermen when they raise their nets and collect the eggs from the ripe fish. This is done by expelling the eggs into a common milk pan in as dry a state as possible, after which they are immediately fertilized by using the milt of the ripe male fish. They are then carefully washed, brought to the station and placed in the hatching jars, where they remain until hatched. In addition to this method of saving the eggs we also pen several thousand fish each year. To do this a net is hung on the back of that part of the pound net called the crib, and when the fish commence coming on the grounds, before they are ripe enough to spawn, the fishermen as they raise their nets take out the unripe fish and place them in these nets on the back of the crib. The station tug, which is provided with large tanks through which a stream of water is constantly pumped, visits these nets and takes the fish out, transferring them to the tanks and conveying them to the station, where they are then transferred to the pens. Here they are held until they ripen, when the eggs are secured; and the fish after a few days, when they have regained their normal condition, are returned to the fishermen from whom they were obtained and are sent to market. It is perhaps well to say in this connection that spawning the fish in this manner in no way injures them for food—in fact these fish that are spawned and then held a few days before being put on the market are in much better condition for consumption than if they had been marketed when first caught. Moreover, the whitefish, unlike many others, is in the best condition for food at spawning time, for the reason that it is very fat and the flesh is juicy, sweet, and, the water temperature at this time being low, firm and flaky, while earlier in the season when the water is yet warm the flesh is much softer and not of as fine a flavor.

Not to digress further, however, we will continue by saying that from the fish collected and held in pens as described above, at one point alone last season over 47,000,000 eggs of the very best quality were secured. In other instances, where the fishermen operate on a small scale and small boats are used for the purpose, arrangements are made whereby the fisherman collects the eggs himself

and is paid for them at so much per quart for fertile eggs. These men operate gill nets and fish on the reefs, and as the whitefish do not frequent the reefs to any extent until ready to spawn, usually more than 50 per cent of their catch is ripe fish.

MEASURES NECESSARY TO INSURE INCREASED PRODUCTION.

From a practical experience of sixteen seasons in the hatching of whitefish and by consultation with other fish culturists, we find that the average hatch of the eggs collected and taken to the hatcheries is from 75 to 80 per cent. Assuming the lower figure to be the correct one, if each pair of whitefish, as previously shown, produce 35,000 eggs, by the assistance of the hatcheries we get three-fourths of 35,000 or 26,331 fry as against the 11 the same fish would have produced if the eggs had been left to themselves, or 2,393 times as many as it was intended by nature for them to produce, as just now shown. Even allowing that the whole of the 1 per cent naturally fertilized hatch, giving 350 fry as the number produced by each pair of fish, the hatchery would still beat nature by 25,981 fry or 750 times as many, and the fry produced in the hatcheries are just as strong and vigorous and their chances for reaching maturity are just as great as are those hatched naturally. Then, if by the lower calculation we produce 750 times as many fry by collecting the eggs and hatching them at the hatcheries as the fish would produce if left to themselves, it is obvious that the best plan to promote the whitefish production of the Great Lakes is:

To so arrange matters that artificial propagation shall be generally applied to reproduction by having hatcheries established at every available point where a sufficient number of eggs can be secured to warrant their maintenance. It is not necessary that the hatcheries be operated on as large a scale as those at Detroit and at Put-in Bay, but wherever enough eggs can be secured to give a hatch of from 25 to 50 millions, if these points are remote from the larger stations put up a hatchery and operate upon as economical a scale as possible; to stock these hatcheries not only collecting the eggs from the ripe fish as caught by the fishermen, but penning and holding the green fish until they ripen, pursuing the method just described, so that practically all the fish caught will have contributed toward this production before being placed upon the market.

To make this plan the more effective, so as to get the greatest increase possible from the fish caught, a law should be enacted compelling the fishermen to collect, or allow the hatcheries to collect, all the eggs from the ripe fish, and to place the green fish in the auxiliary nets for penning; the fishermen to be paid a fair price for the eggs so taken by them and for their trouble in penning the fish, and to receive a fair remuneration for all fish lost by penning.

As a further part of the plan we would have a law enacted prohibiting the taking or the offering for sale of any undersized whitefish, making the size limit large enough so that every fish before being placed upon the market would have had a chance to have spawned at least once and thereby contributed toward increasing the production.

This plan should not only be universal with the states bordering upon the Great Lakes, but should be international, making the same conditions on the Canadian side as in the states and preventing any loophole through which the regulations could be evaded.

This plan would be strengthened by making a closed season during the summer months when it is so nearly impossible to get the fish to market in an edible condition on account of the warm weather and the high temperature of the water from which they must of a necessity be taken. All the fish so taken are a total loss to reproduction, as they go to market with all their unripe eggs still in the ovaries, and for every female whitefish taken at this period there is a loss to reproduction of 11 to 350 fry if left to spawn naturally, or of approximately 26,000 if the eggs were allowed to ripen and hatch at a hatchery.

If this plan is adopted, the writer will cheerfully stake his reputation as a fish culturist that at the end of ten years it will have been proved the best offered up to date.

A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES

By Frank N. Clark

Superintendent U. S. Fisheries Station, Northville, Mich.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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In preparing the following discussion I considered it desirable to eliminate as far as possible the complicated and tiresome statistical details which, in almost every paper of this nature, go to make up a great portion of its subject-matter. I believe that the interest of those who may be called upon later on to devise some effective means of increasing the supply of this greatest of all American food fishes will be more easily aroused by demonstrating a simple and practicable solution of the problem. Some figures are necessary, of course, but in most instances I have made bold assertions of facts which I know to be true, and which I am going to take the liberty of asking my audience to accept for the truth.

CONDITIONS OF THE FISHERY AND THEIR CAUSES.

It is a universally conceded fact that in an early day when the forests of the states and provinces bordering upon the Great Lakes were for the most part still in their primitive splendor, when the rivers and streams emptying into these waters ran clear as crystal and when civilized man had not yet turned so extensively to the waters for his livelihood, whitefish were in very great abundance and were distributed in a wide range throughout the entire water system known as the Great Lakes. Even as late as from 1864 to 1870, as may be noted by reference to Mr. J. W. Milner's report in the Bulletin of the United States Fish Commission for the year 1872, whitefish were present in such large numbers that during a single season it was not unusual for a fishing ground to yield from 200 to 700 half barrels for each pound net in operation. In a long and very interesting conversation which I had a few years ago with a Mr. Woodward, who was then a very old man, I learned that sometime during the early fifties, while he was acting as a government surveyor and maintaining a camp at the mouth of the Thunder Bay River, his party caught more whitefish than it could use and took them all from the river itself. At the present time no whitefish

are caught within 9 miles of the river's mouth. In 1867 and 1868 my father, the late N. W. Clark, who was one of the pioneer fish culturists of America, took whitefish spawn on the Detroit River, and his observations made at that time indicate that the species was very abundant. At Grassy Island and Mama Juda, two of the best-known fishing grounds, 1,000 fish at a haul was no unusual occurrence. At the present time a haul of 30 fish is considered large. The same is true also of the Au Sable region upon Lake Huron, where during the sixties from 40 to 50 boats were doing a very lucrative business and at the present time not more than a half dozen are operated with only indifferent success. In varying degrees this same decrease in numbers has taken place upon every fishing ground of the Great Lakes, in a great many places to such an extent that operations have been entirely abandoned.

Why should this be so? If we can answer this question, and if the causes can be eliminated or in some measure restricted and controlled, we will have found a solution of our problem in so far as a solution is possible.

First. The cutting of our forests and consequent floods and erosion of the soil, the discharge of sawdust and other refuse from the lumber and pulp mills, chemical works, and sugar factories, which go to make up the industrial life of the cities situated on the Great Lakes, have made the deposits from the mouths of our rivers offensive to the dainty senses of the whitefish and have gradually encroached upon its spawning and feeding grounds to such an extent that in thousands and thousands of acres which at one time were teeming with this species it is now an absolute stranger. This damage can not now be undone, but by wise legislation the cause of it may be to some extent prevented from further offenses.

Second. The operation of the commercial fisheries under unwise laws and the nonenforcement of good laws has, in my judgment, contributed in a greater degree toward the decrease of the whitefish than all of the other causes put together. Most of the law-making bodies of the states bordering upon the Great Lakes have put the cart before the horse, so to speak. By their enactments they have permitted the taking of this fish at all times except during the spawning season and the period of incubation, which all students of fish culture insist is a kind of alleged protective legislation that does not protect. If we are to have closed-season laws they should cover the month or months when the largest lifts of unripe fish are made. It is then that our whitefish need protection, for their ova are immature and we can not half so well spare the parents as we can during the spawning season. When unripe adults are caught for market all their spawn is necessarily wasted, whereas if protected until the spawning season the different commissions would be given an opportunity to save the ova, hatch the fish, plant them in the lakes, and thus by artificial propagation cause each ripe female to furnish thousands of her kind. We have

hatcheries to care for the ova, and, if the present number is insufficient, let us build and equip others; in any event let us not expect nature to make a complete revision of her fundamental laws merely to accommodate herself to the lack of foresight and the inconsistency of mankind.

We need no protection for mature fish, except, as above stated, during the months when the largest lifts of unripe fish are made. The young fish should be protected against the adults. These are the enemies and food competitors of the growing generations, and the quantity of food that a dozen adults consume will suffice for the support of thousands of fry. The question may properly be asked, do the fry subsist upon the same individual food that the adults require? Strictly speaking, they do not; but the source from which the growing generations derive their food supply is at least indirectly dependent upon the higher groups which the adults do destroy.

For these reasons, therefore, I contend that the so-called closed-season laws as they now exist are all wrong. Of course, I am not one of those enthusiasts who believe that our lakes may be made to teem once again with the countless millions of the early days, even with the assistance of the wisest possible legislation and most successful artificial propagation. The conditions have been changed and I know of no way whereby they can be restored. The formerly vast and almost unlimited areas of spawning and feeding grounds have been gradually destroyed by sawdust, bark, slabs, water-logged timber and other refuse, and the water for miles out from shore in the neighborhood of cities and towns is constantly being polluted and infected by poisonous sewage and other impurities. Because of these unfortunate conditions the present spawning and feeding grounds are confined to a few localities.

REMEDIAL MEASURES.

But that the whitefish of the Great Lakes can be increased very materially in spite of these difficulties which the fish culturist is forced to encounter I am very strongly convinced. This can be done only by closely adhering to some such plan of action as I shall outline in the remainder of this paper, and which I contend, and shall endeavor to convince my hearers is the only possible solution of the problem.

(1) INTERNATIONAL PROTECTIVE LEGISLATION.

First, there must be concerted action, by means of a treaty or otherwise, on the part of the United States Government and the Dominion of Canada, and such action must be carried on to the point where there shall be one set of laws applicable to all the waters of the Great Lakes and their tributaries, and enforceable on the part of either government in any part of its own or

the other's territory. I would also repeal and abolish all of the existing laws of the several states and provinces in so far as they deal with the food fishes of the Great Lakes, so that the question of proper authority and jurisdiction could never arise. The greatest advantages to be gained by thus placing the Great Lakes under the control of the two governments would be the more rigid enforcement of the laws and the removal of legal proceeding from the universally conceded local influence over local juries. A uniform law such as I deem to be adequate to afford the fullest measure of protection for the whitefish should be framed along the following lines:

(1) Issue to the present United States and Canadian fishermen, or to anyone who shall subsequently apply therefor, a revocable license to fish the waters of the Great Lakes and their tributaries; such license to be suspended for six months for the first violation, one year for the second, and forever forfeited without hope of reinstatement upon a third violation of the protective laws.

(2) Provide for an open season during the months when the fish are spawning and a closed season during the month or months when the largest lifts of unripe fish are made.

(3) Prevent any sort of fishing in certain localities where large numbers of immature fish congregate upon the feeding grounds, this legislation to pertain to all portions of the Great Lakes system where the presence of such fish has been established and to be enforced during such month or months as they make their appearance in large numbers for feeding purposes.

(4) Prevent the sale or offering for sale or the use of immature whitefish in any manner except for charitable purposes, the size of a mature fish to be legally fixed for this purpose at 2½ pounds. This would discourage the capture of immature fish and protect them upon their feeding grounds, where they assemble in schools.

(5) Make no restrictions of any kind whatsoever as to the kind of nets or the size of the mesh which the fishermen may use in their operations, because, in my judgment, the provisions of this character which are now a part of the present local laws have furnished even more opportunities for the fishermen to escape conviction than the influence upon local juries. Rigidly enforce the provisions regulating the size of the fish which may be sold, and the size of the mesh, kind of net, and manner of capture will be regulated by the fishermen themselves.

(6) As a part of this legislation let there be a provision requiring all fishermen who operate in the territory comprising the Great Lakes and their tributaries to take and fertilize all of the spawn contained in every ripe female that is caught during the spawning season, further details of which plan I shall discuss under another topic.

The above-outlined six provisions would, in my judgment, constitute an adequate law for the greatest protection and consequent increase of the whitefish that it would be possible to give them. If a uniform law can be agreed upon and framed along these lines, and then enforced with the same watchful diligence with which the revenue laws of both countries are enforced to-day, there is no room for argument against the statement that, aided by artificial propagation on a large scale, the whitefish may be increased so materially that at no very distant future date the fisherman's net will be found to contain dozens where there is one to-day.

(2) ARTIFICIAL PROPAGATION.

Now while a uniform, adequate, and rigidly enforced set of laws is of the greatest necessity in bringing about a material increase in the whitefish, propagation upon a large scale is absolutely indispensable. That artificial propagation of the whitefish as it has been worked out and practiced during the past twenty years by the several states and the United States and Canadian governments has been the means of effecting an actual increase of this species, there is at this day no one so bold that he dare dispute. Statistics have been prepared and published which show that until within the past six or seven years from two-thirds to three-quarters of all plants of whitefish fry have been in Lake Erie and the Detroit River, and the fact is well known that in these waters there has been a large increase in their numbers. The United States Government during its operations at Belle Isle and Grassy Island in the Detroit River for the past few seasons has taken from 25 to 50 per cent more whitefish at these points than the Michigan Fish Commission did a decade ago, the fishing continuing for no longer a period each season and being with the same kind and length of seines.

Now, by artificial propagation on a large scale I mean the production of whitefish fry in such numbers that every suitable locality on the Great Lakes may have the same, or, if possible, greater opportunities to assist in this increase than have been afforded Lake Erie and the Detroit River. This would involve the planting of from two to five billion fry annually, and the following plan, if adopted, would easily furnish, in my judgment, a sufficient number to bring about the required results:

Every fisherman operating in the waters of the Great Lakes should be required to strip every ripe female caught during the spawning season and impregnate the eggs taken therefrom. This would operate as an annual tax upon the fishermen, the expense being probably from $25 to $100 per boat. At the present time from 50 to 75 per cent of the fishermen are perfectly familiar with the methods employed in successful spawntaking, and there

would be very little difficulty in having the inexperienced taught by the experts in the employ of the two governments. After impregnation all of the spawn should be turned over to United States and Canadian government agents for shipment to the several hatcheries, where the eggs could be cared for and the fry distributed in a wide range throughout the entire Great Lakes system. The eggs taken by each fisherman should be measured and kept separate from the others throughout the incubation period. This would involve but very little additional labor and would be of very material assistance to those agents of the two governments upon whom would be placed the responsibility of enforcing the protective laws; and such a record would not only show exactly which fishermen were improperly impregnating the eggs taken, but by comparison with the size of their catch during the spawning season it could be satisfactorily determined whether or not they obeyed the law prescribing that all ripe females should be stripped. Of course, a fisherman might be the victim of ill luck throughout one season, but a recurrence of an unsatisfactory showing would put him under suspicion, and with the penalty of a forfeiture of his license hanging over his head he could be very easily made to see the error of his way. Finally, the Detroit River must be closed to all fishing at all times, except with rod and line, and must be constituted a joint government reservation, controlled and used by the two governments for collecting stations.

If the present facilities for handling the product from these two sources are not sufficient, hatching and distributing stations can be arranged for easily and without any great amount of expense. Such a station with a producing capacity of 50,000,000 fry can be constructed and equipped at a cost not exceeding $1,500, and the same can be operated at an annual expenditure of $500.

This is my plan, in the rough to be sure, but with its essential outlines sufficiently distinct to make the work of preparing and putting into execution an adequate system for the proper protection and consequent increase of the whitefish in the Great Lakes a comparatively easy task. It is self-evident that, inasmuch as the life and growth of the whitefish industry of our inland seas are directly dependent upon the maintenance of supply, the plan which will best promote the industry will be the one which will insure the greatest increase in the species.

A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES

By Paul Reighard

University of Michigan, Ann Arbor, Mich.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded the prize of one hundred dollars in gold offered by the Wolverine Fish Company, of Detroit, Mich., for the best plan to promote the whitefish production of the Great Lakes

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A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES.

By PAUL REIGHARD,
University of Michigan, Ann Arbor, Mich.

APPROACH TO THE PROBLEM.

In attempting to devise a plan for the promotion of the whitefish production of the Great Lakes it appears that certain avenues of approach available in the case of cognate problems are in this case closed. This will perhaps become clear if we first consider the possible modes of accomplishing the purpose. The procedures that suggest themselves are those which might be followed in any like problem, and may be conveniently grouped in the following way:

Preservative measures:

1. Prevention of the water pollution which may occur through the agency of sewage, garbage dumps, sawdust or other manufacturing refuse, cinders, ashes, and other refuse from steamers and other boats.
2. Restriction of fishing operations (limitations on fishing season and on character and number of nets to be used).

Restorative measures:

3. Distribution of fry.
4. Introduction of improved races of whitefish.
5. Increase of the food of the whitefish.

Experiments on the effect of water pollution on fish have been conducted abroad and are summarized by Professor Prince (1900). The investigations carried out for the Canadian government by Mr. Knight (1901 and 1907) on the effect upon fish of the pollution of Canadian streams by the refuse of sawmills, pulp mills, gas works, and nail mills are noteworthy, but do not appear to have any application to the Great Lakes. In this country we appear to have no similar published investigation, so that we have no means of knowing the extent of water pollution in the Great Lakes or its effect on the whitefish. We are therefore compelled in this paper to disregard a possible means of increasing the whitefish production through the prevention of water pollution.

When it is desired to increase the production of domestic plants or animals, this is often most readily done by increasing the food supply. In other cases the result may be accomplished by creating a race of larger individuals, or one that breeds more rapidly. These two methods have been applied to domestic forms, but the first of them is often made use of also with game birds and mammals. The whitefish of the Great Lakes lives at depths of from 10 to 50 fathoms, scattered over an area of 25,700 square miles. (See p. 653.) Our knowledge of its mode of life, its daily and yearly movements, and its whereabouts during the growth period is meager. It is impossible, therefore, with present knowledge and under existing conditions, to attempt to increase the natural food of the whitefish. To suggest that it may be possible to produce a race of whitefish that would breed more rapidly than our present race, or appropriate food not utilized by the present whitefish, or occupy areas of the lake bottom now barren of whitefish, is to state a problem the solution of which must lie far in the future. The breeding of improved races of fish must begin with forms more readily controlled than the whitefish. There remain but two methods by which we may hope to increase the whitefish production of the Great Lakes, namely, to greatly increase the number of artificially hatched fry introduced into the lakes annually or to enact restrictive legislation which shall prevent the further depletion of productive waters and shall at the same time give an opportunity for depleted waters to become again productive. The present paper attempts a discussion of these two methods (2 and 3 of the foregoing analysis).

METHOD OF INVESTIGATION.

In undertaking an inquiry of this sort it is impossible to make personal investigation of the whitefish in the field. The vastness of the areas involved and the depth at which the fish lives precludes this in the case of the individual investigator. He must necessarily base his work on data gathered by those who have worked with the help of the various state and national governments bordering on the Great Lakes. The problem is essentially one of statistics. The investigator wishes to know what amount of whitefish have been taken in each part of the Great Lakes over a long period of years; what kinds and quantities of nets have been used in their capture; under what legislative restrictions these have been used; what quantities of young fish have been introduced into the Great Lakes and into each part of them to replenish the waters from which the adults have been taken.

Fishing operations are carried on, or have been carried on, wholly by private individuals or corporations in the waters of the following States: Indiana, Illinois, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, as well as in the waters of the Dominion of Canada. The fishery laws of these various governments are diverse, and have been changed from time to time in the past. It is

therefore difficult to find any well-defined area in the American waters of the Great Lakes which has been fished under uniform conditions for a period sufficiently long to permit conclusions to be drawn as to the effect of that fishing.

Not only have the conditions under which the fishing has been carried on varied from time to time in any one locality and at any one time from locality to locality, but no complete records are available of the fishing operations in the Great Lakes as a whole, or in any single lake, except Lake Huron, for any continuous period of years. The United States Fish Commission (now the Bureau of Fisheries) has caused statistics to be collected on the fisheries of the Great Lakes about once in five years, and these are available for the following years: 1880, 1885, 1890, 1893, 1899, 1903. The Michigan fish commission has since 1891 employed a statistical agent, who has annually visited each fisherman and personally taken from his books the records of the fish caught and of the nets used. The Canadian Department of Marine and Fisheries has for the past thirty-eight years published in its annual report detailed statistics of the fisheries in Canadian waters. The remaining governments, with the exception of Pennsylvania, are able to afford no information about the fishing operations within their borders.

Not only is investigation hampered by the paucity of statistics, but the reliability of the available statistics is often a matter of serious question. The difficulties in dealing with whitefish statistics arise from two sources. Even when statistics are available for like periods and over the same areas they are often widely at variance. The Michigan statistics are taken annually by a statistical agent who is in the field almost constantly and who by his long service, begun in 1891, has gained the confidence of the fishermen. They are taken under a law which requires the fishermen to make sworn returns of their catches. Considering all the circumstances, they are probably as accurate as such statistics can be made. The data that it has been found possible to use in this paper are chiefly those of the Michigan and Canadian fisheries.

The second source of difficulty referred to has to do with the use of the term "whitefish." Four fishes of commercial importance are referred to as whitefish. These are the common or true whitefish (*Coregonus clupeiformis* Mitchill), the longjaw (*Argyrosomus prognathus* H. M. Smith), the blackfin, bluefin, or bloater (*Argyrosomus nigripinnis* Gill), and the Menominee whitefish (*Coregonus quadrilateralis* Richardson). Subsequent to 1891–92 these forms are distinguished in the statistical reports of the United States Fish Commission, but previous to 1893 "whitefish" only are mentioned. The published reports of the Michigan Fish Commission, as well as the unpublished records of their statistical agent, exclude menominees, blackfins, and longjaws from the rubric "whitefish," which therefore includes only true whitefish. The statistics collected by the Department of Marine and Fisheries of the Dominion of Canada, I am assured, include true whitefish only and exclude longjaws and blackfins. Our com-

parisons are therefore necessarily limited to the whitefish production of those waters that lie within the borders of the Dominion of Canada and of the State of Michigan for the period 1892 to 1906, inclusive, and to the Great Lakes as a whole for the years subsequent to 1893. In the latter case, however, statistics are available only at five-year intervals.

The distribution of whitefish fry is carried on at the expense of the state and national governments, and the annual official reports therefore contain full statements as to the number of fry distributed and the location of each plant. Whitefish fry have been distributed by the states named above with the exception of Illinois, Indiana, and Minnesota, and by both of the national governments, although the states of Ohio and Michigan have not distributed whitefish fry in recent years.

By combining the statistics of the Michigan fisheries with those of the Dominion of Canada, complete returns are available of the catch of whitefish and of the nets used for Lake Huron for the years 1892 to 1906, inclusive. The exact number of pounds of whitefish brought in by each fisherman on this lake and the precise length of the nets used in the lake are recorded for each of these fifteen years. The plant of whitefish fry in this lake may be obtained by combining the figures of the Michigan and Canadian plants for the whole lake or for any part of it. We may thus study in this lake, or in any part of it, the effect of the distribution of whitefish fry on the catch of adult fish for a period of fifteen years. By comparing Canadian and Michigan waters for the same period, we may study the effect on the production of whitefish of certain restrictive enactments which have been enforced in Canada but not in Michigan. By similar methods we may study certain areas in Lakes Superior, Michigan, Erie, and Ontario, from which we have statistics from either Michigan or Canadian sources.

In statistics of the catch of whitefish, figures of single years have little significance, since the catch of one year may be large owing to the weather conditions of that year having been favorable for fishing, while the catch of another year with which the first may be compared may be small owing to unfavorable weather conditions during that year, or the market price in one year may have been high, with a consequent stimulation of fishing operations, while in another year it may have been low, with a consequent curtailment of those operations. These annual fluctuations make it necessary to compare with one another not single years but periods of years. In the present paper market fluctuations are not considered, since the price of whitefish does not tend to fluctuate but rather increases steadily, while by comparing the average outputs of the three successive five-year periods comprised in the years 1892 to 1906, inclusive, an attempt is made to avoid the errors introduced by annual variations in the weather of the fishing season.

The condition of the fisheries is usually expressed by giving the annual catch, but as was pointed out by Rathbun and Wakeham (1893), "the best statistical test of a decrease is a comparison of the average catches per unit of apparatus for the several years for which statistics are available." In comparing the catches of different periods I have therefore reduced the average catch of each period to "pound-fathoms" by dividing the actual catch expressed in pounds by the length of gill and pound nets expressed in fathoms. I have thus obtained the catch in pounds per unit of net length. Unfortunately in making these calculations I have been unable to separate the gill and pound nets which have taken whitefish from those which have not, so that the values given in the tables in this paper are the lengths of all gill and pound nets used in the waters in question whether the nets have or have not taken whitefish.

I have attempted, also, to consider the output of whitefish in its relation to the areas of the Great Lakes bottom occupied by them during that season of the year when they are not migrating. By dividing the number which expresses in pounds the catch of a lake or of any part of a lake by the number of square miles of lake bottom ordinarily occupied by the fish in question, I have obtained a pound-mile unit which is made use of in another part of this paper, where also the method of measuring the areas is described. By the device of the pound-mile it is hoped that in a measure errors have been avoided which arise from the comparison of the catches of different years when the areas fished over in those years have not been the same.

The present paper then attempts to utilize the available statistics in an examination of the individual Great Lakes and of parts of lakes to see what lessons may be learned by a comparison of those areas which have been fished under one set of regulations with those that have been fished under a different set of regulations, and by a comparison of those areas which have been abundantly planted with those that have been less liberally treated. I am indebted to the United States Bureau of Fisheries for kindly obtaining information for me from the states of New York and Pennsylvania, to the Wisconsin Fish Commission for information furnished, to the Michigan Fish Commission for permission to make excerpts from the original records on file in their office and as yet unpublished, and to the Department of Marine and Fisheries of the Dominion of Canada for printed documents and excerpts from official records.

NATURAL HISTORY OF THE WHITEFISH.

SOURCES OF INFORMATION.

In the report of the joint commissioners relative to the preservation of fisheries in waters contiguous to the United States and Canada, Messrs. Rathbun and Wakeham (1897) have collected a large amount of evidence concerning the

habits of the whitefish. This evidence, which is summarized in the report referred to above, consists of the statements of fishermen as to the depths at which whitefish are taken in the different lakes, their distribution, migrations, and other habits. This report, together with the statements of Prof. H. B. Ward in his report on Lake Michigan in the Traverse Bay region (Ward, 1896) form the basis of the following account. The earlier works of Milner (1874) and Smith (1893) have also been consulted.

KINDS OF WHITEFISH.

By the term whitefish as used in this section of the present paper is to be understood the true whitefish or common whitefish (*Coregonus clupeiformis* Mitchill) unless otherwise stated. Fishermen, while they distinguish readily between the true whitefish and other related species, nevertheless often report them together as whitefish and statistical reports are necessarily based on their statements. Thus in the most recent statistical reports of the United States Bureau of Fisheries, Alexander (1905) separates whitefish, longjaws, and bluefins in Lakes Superior and Michigan, and whitefish, longjaws, and menominees in Lake Huron, but lists whitefish only in Lakes Erie and Ontario, although the latter lake, at least, contains longjaws (Smith 1895). The Michigan and Canadian statistics refer to whitefish only. The data used in the present paper are those which refer to true whitefish only.

DEPTHS AT WHICH WHITEFISH OCCUR.

The following statements as to the depths at which whitefish are found are taken from Rathbun and Wakeham (1897) except that for Lake Michigan, which is from Ward (1896):

	Fathoms.
Lake Ontario	10–20
Lake Erie	12–30
Lake Huron	10–35
Lake Michigan	12–20
Lake Superior	10–50

The depth data given for Lake Michigan are specifically stated by Professor Ward to be depths of the true whitefish in summer, and to be the range over which the fish is the most numerous. It occurs in small numbers in both shallower and deeper water. The depths given for Lakes Ontario and Erie are no doubt also those at which the true whitefish is found during the greater part of the year. The greater depths given for Lake Huron possibly cover also the range of the longjaw, which is stated by Ward to occur in greatest abundance from 20 to 25 fathoms in Lake Michigan, although Smith (1895) states that in Lake Ontario they range as deep as 116 fathoms and in August as shallow as 20 fathoms. The range in Lake Superior also possibly covers more than the

true whitefish, but this is uncertain. It may cover in part the range of the blackfin (*Argyrosomus nigripinnis*), which is stated by Ward to be in Lake Michigan rare in less than 40 fathoms. I have placed the inshore range of the whitefish of Lake Superior at 10 fathoms, although Rathbun and Wakeham make no statement on this point, but say merely that the fish ranges "outward into depths of 40 to 50 fathoms, seldom farther, and in some places coming close upon the shore during the spawning season and in the spring." I have assumed the inshore range on Lake Superior to be about the same during most of the year as in the other lakes.

The most careful investigation of the food of the whitefish and of the related fishes we owe to Ward (1896), who finds as a result of the examination of 14 individuals taken in summer that on the average 63 per cent (by volume) of the food of the true whitefish consists of small bottom crustaceans, 26 per cent of small mollusks, 5 per cent of insect larvæ and 2 per cent of small fish. Small brown stones were also found commonly in the stomachs. "The considerable part played by the mollusks and insect larvæ, both of which are strictly bottom forms, shows that the common whitefish is to a large extent a bottom feeder. This view is strengthened by the down-pointed sucker-like mouth of the fish as well as by the presence in the stomachs of numbers of small stones, which were undoubtedly snapped up with some morsel of food" (Ward, 1896). The food of the longjaw Ward found to consist of small crustacea to the extent on the average of 97 per cent of the whole (volume), while the food of the two specimens of blackfin examined contained crustacea to the extent of 97 per cent of the volume. The absence of stones, mollusks, and insect larvæ from the stomachs of these two forms and the presence in them of free swimming crustacea, as well as the form of the mouth of the fish themselves, show that they feed not on the bottom, but just above it. All of these whitefishes therefore feed on the bottom or just above it, but differ in their depth range during the greater part of the year, the true whitefish ranging from 10 fathoms outward, but rarely being taken in more than 35 fathoms, the longjaw ranging from 20 fathoms outward, occurring in greatest abundance between 20 and 25 fathoms and reaching in winter a depth of 116 fathoms, the blackfin occurring rarely in less than 40 fathoms and most abundant at 70 fathoms and upward.

The ranges indicated above as occupied by the whitefish are its feeding grounds during eight or nine months in the year. It enters shallow water in the southern lakes in June and July, and returns again to the deeper water about the 1st of August. The cause of this shoreward migration is discussed by Milner (1874), but he does not mention one very probable cause, namely, that the period of this shoreward summer migration is that when the insect larvæ upon which the migrating fish feed (Kiel, 1874) are most abundant. It is quite possible that the migration takes place as a search for a more abundant

food. The summer migration of the whitefish occurs apparently in all the Great Lakes. Milner (1874) reports it in Lakes Superior, Michigan, Huron, and Ontario, and Rathbun and Wakeham (1897) report it in Lake Erie. The date of its occurrence no doubt varies with the latitude. A second inshore migration occurs in the fall, taking place in November in the more southern latitudes and occupying about a month in any latitude. It is the spawning migration, during which the fish visit the shallower water to deposit their eggs. From Lake Erie this migration formerly extended to the St. Clair River and Lake St. Clair and it still extends into the Detroit River, but in the other lakes the location of the spawning grounds and the related extent of the migration are little understood.

Milner states (1874, p. 85, 92) that the fish do not eat while spawning, or have very little in their stomachs. In this respect their habits are like those of many other Salmonidæ under like circumstances. If we accept this statement, then the food of the whitefish, except during the spring migration, is obtained within the depth range indicated above. During nine months of the year they are on this range; during June and July in southern latitudes and probably for a corresponding period in more northern latitudes they are engaged in the so-called spring migration; during one month (November in southern latitudes) they are engaged in the spawning or fall migration and during this time they do not feed or feed very little. The existence of the species therefore depends on the utilization of the range referred to. The capacity of any of the Great Lakes to produce whitefish must depend on the extent of this range, assuming the existence of suitable spawning grounds. If we accept Milner's statement (1874, p. 61–62) that young whitefish of less than 1¼ pounds weight are found in water from 20 to 45 feet deep and thereafter enter deep water, the above proposition still stands essentially unmodified, for the production of commercial whitefish or breeding whitefish would still be in relation to the area of the range which furnishes them with food during nine months in the year. These areas I shall refer to hereafter as whitefish areas.

AREAS OF BOTTOM FREQUENTED BY WHITEFISH.

In the accompanying maps (fig. 1 to 5) we have attempted to indicate the extent of the whitefish areas for each of the Great Lakes. These are the areas within which the fishermen find the whitefish when carrying on commercial fishing operations at other times than during the fall and spring migrations. They are the areas over which it is, or has been, profitable to fish, and outside of which the whitefish is found in relatively small numbers. The maps have been made by tracing the appropriate fathom lines on the United States engineer charts of the Great Lakes. They are sufficiently explained in the legends

attached to them. In the following table we have given the whitefish areas for each of the Great Lakes together with the extent in square miles of the lakes themselves. These whitefish areas have been obtained by measuring with a planimeter the areas plotted on the maps. The lake areas are taken from H. M. Smith, 1894.

AREA OF EACH OF THE GREAT LAKES, WHITEFISH AREA OF EACH, AND PERCENTAGE OF WHITEFISH AREA.

	Total area.	Whitefish area.	Percentage of whitefish area.
	Square miles.	*Square miles.*	
Lake Superior	32,000	7,400	23
Lake Michigan	22,000	2,600	12
Lake Huron	21,000	9,400	45
Lake Erie	9,500	4,100	43
Lake Ontario	6,500	2,200	34
Total	91,000	25,700	28

It is to be noted that the area occupied by the true whitefish is relatively least in Lake Michigan, where it forms but 12 per cent of the lake area. Lake Erie comes next with a whitefish area 14 per cent of its total area, if the eastern part of the lake only is taken, but if the western platform of Lake Erie be included over depths of 12 to 30 fathoms, its whitefish area is raised to 4,100 square miles, or 43 per cent of that whole area. Whitefish are taken on those parts of the platform of suitable depth, but in relatively small numbers.

MIGRATIONS.

The whitefish do not wander about at random in these areas, so that the fish of one lake pass into another lake, or those of one part of a lake to a distant part of the same lake. On the other hand, such evidence as we have indicates that the whitefish, like other fish, are during the greater part of the year local in their habits. Their migrations during the breeding season have been already sufficiently referred to, so that we need consider here only the wanderings of the fish during the rest of the year. In general it may be said that the wanderings of fish are by no means fortuitous and, except in the breeding season, are of limited extent. This subject is discussed at some length by Professor Prince (1907) and need not detain us further here. The relative local habits of the nonmigrating herring in England, of the shad in this country, and of the salmon are now well understood. It is well known to fishermen and to dealers who handle whitefish that the fish of different lakes are so unlike that one who is accustomed to them can readily distinguish them. Each lake has its own race and these races do not intermingle by running from lake to lake.

LOCAL HABITS OF WHITEFISH.

Not only does each lake have its race of whitefish, but there are reasons for the belief that parts of lakes are inhabited by races peculiar to them. On this point Milner (1874, p. 47) has the following to say:

> The presence of large whitefish in numbers in certain localities on the north shore of Lake Michigan, of a size that are never taken at other parts of the lake, would indicate a local habit, with no disposition to range through long distances.
>
> Another observation, sustaining the probability of this, is the fact that there are many localities on the lakes where the pound nets, a few years ago, found prosperous fishing, and in the first few years took the whitefish in great abundance, but found afterwards a decrease from year to year until the locality was abandoned, while 50 miles away the business continued successful.
>
> * * * * * * *
>
> The fact that certain types of whitefish are peculiar to certain localities, as the north shore of Lake Michigan, the Sault Ste. Marie Rapids, Bachewauna Bay on Lake Superior, indicates a local habit through many generations until certain characters of a race have become established. The same fact has been stated for the shad on the Atlantic coast.
>
> Some observations made in 1871 perhaps indicate the opposite of all the foregoing statements.
>
> In the early part of the season there had been a few fish caught on the west shore of Lake Michigan between Chicago and the Door Islands. South of Chicago, at the mouth of the Calumet River, the run of whitefish was in excess of anything had for years. But about the 15th of June the schools of fish left Calumet, and a few days later there was a decided improvement in the catch at Evanston. About June 22 the lifts at Waukegan began to be heavier than they had been before. During the first week of July the fishing was observed to improve at Milwaukee, Manitowoc, Baileys Harbor, and, a little later, at the Door Islands.
>
> The coincidence in dates rather indicates that the same schools of fish that clogged the nets at Calumet during six or seven weeks had ranged northward along 260 miles of coast. Still the effect upon the fishing would have been the same if it had been the migrations of schools of fish from deep water at these points in to the shore.

The explanation here offered by Milner, that the phenomenon described in the paragraph is indeed due to the inshore migration of local groups of whitefish beginning at the southern end of the lake and proceeding northward on the west shore, is most probable and is in harmony with the other facts which he cites, as well as with what we now know of local races in other species of fish.

We are concerned here only with those movements of the whitefish which take place out of the spawning season, yet it may not be without interest to cite further from Milner to show that even during the spawning run the movements of the fish are more local than would be thought. He says:

> It is a singular fact that the whitefish are not known to descend from Lake Huron into the St. Clair River. This is established by abundant evidence from continued fishing at Fort Gratiot, where Mr. Clark, between the years 1830 and 1842, took large quantities of the wall-eyed pike, *Stizostedion americana*, taking frequently 1,000 barrels a year. The catch of whitefish amounted to an occasional supply for his own table, except after long continued storms from the northward, when the fish sometimes entered

the river in schools. They were never found in this portion of the river in the spawning season.

The same fact is claimed by the Indians in the Sault Ste. Marie River, that the whitefishes of the lake above never descend the rapids, while the whitefishes of the river, it is also asserted, never ascend to Lake Superior. There is not as good evidence for the truth in this locality as at Fort Gratiot; still it may be the case.

The evidence collected by Rathbun and Wakeham points also to the local habit of the whitefish of Lake Ontario. They say (p. 60):

> There does not seem to have been any regular migration of these fish lengthwise of the lake. They occurred along a narrow border of the lake and simply moved to feeding grounds in the spring and to spawning grounds in the fall wherever the shoal water was suitable. There they were most abundant, and on these areas we still find the remnant of them.

Again they say of Lake Huron:

> The movements of the whitefish in Lake Huron are, in general, less definite than in Lake Erie, being confined to shoreward migrations in the spring and fall. These migrations appear to be accompanied by no extensive progress alongshore, except at Detour, where the spring run is said to have a general easterly direction, appearing first near Detour and then passing down the North Channel into Georgian Bay.

It would be easy to compile evidence from the statistical returns of the Michigan fish commission to show the local habit of the whitefish, from the fact that fisheries have often been depleted in one locality while remaining profitable in other localities 25 to 50 miles distant, but the facts already cited seem to be sufficient for the purpose.

WHITEFISH AREAS OF GREAT LAKES.

An examination of the whitefish areas as platted on the accompanying maps tends to strengthen this view of the local habit of the whitefish. In Lakes Superior, Ontario, and Michigan we see this area stretching in a relatively narrow zone along the whole shore. This zone incloses a central area of deeper water which separates the whitefish area of one side of the lake from that of the other side and is probably never crossed by these fish. Within it occur the blackfins and longjaws. In Lake Huron we see a similar condition of affairs for the main lake, but in Georgian Bay we find the greater part of the area taken up by whitefish grounds. Here the deep water is not central in the whitefish area but is displaced toward the southwest so as to leave the marginal whitefish area very narrow on one side of the lake and very broad on the other side. In the North Channel of Lake Huron a continuous whitefish area occupies its center uninterrupted by a deeper middle water. In this lake the reef which cuts obliquely across the main lake is said not to harbor whitefish in commercial quantities and not to afford them spawning ground. It is therefore not included in the whitefish area, although of suitable depth, and its extent is indicated on the map in outline only.

FIG. 1.—LAKE SUPERIOR.

Whitefish area (shown in black), 10 to 50 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1474. Scale: 1 in. = about 44 miles.)

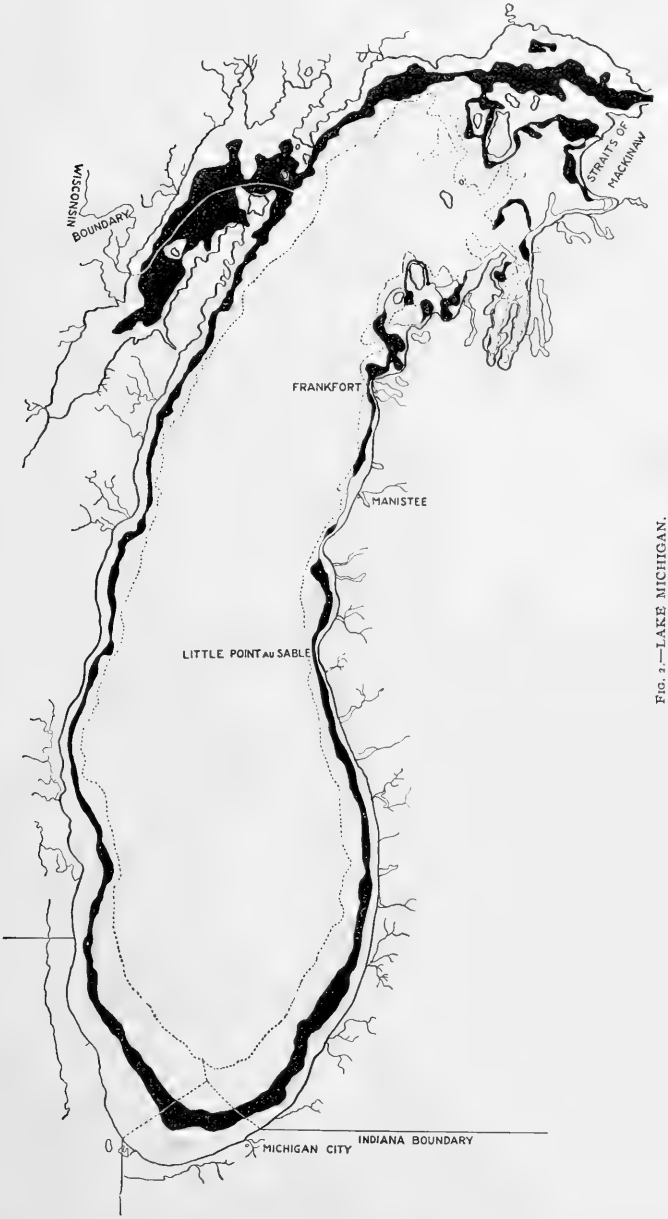

FIG. 2.—LAKE MICHIGAN.

Whitefish area (shown in black), 12 to 20 fathoms and (to dotted line) 20 to 40 fathoms. (Reduced from U. S. Hydrographic Engineer chart. Scale: 1 in. = about 41 miles.)

In Lake Erie the whitefish area is divided into two portions—a western, which occupies the central portion of the lake west of Conneaut and is not interrupted by deeper middle water, and an eastern, which lies eastward of Conneaut and contains a small central middle portion of deeper water. The two portions are connected by a narrow neck at their southern borders. So far as I can learn the whitefish appear to confine themselves during most of the year to the eastern portion of this area, though for what reason is unknown.

FIG. 3.—LAKE HURON.

Whitefish area (shown in black), 10 to 35 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1478. Scale: 1 in. = about 46.8 miles.)

More careful examination of the maps shows that while the whitefish area is continuous in most of the lakes about the whole border, this is not the case in Lake Michigan. Just south of Little Point Au Sable the area is nearly interrupted, and to the north of this it breaks up into numerous small areas which are either detached from one another or nearly so. Of course if the deeper

limit of the whitefish area had been taken as 30 or 40 fathoms the area would become more nearly continuous. In selecting 20 fathoms as the deeper limit of this area in Lake Michigan I have been guided by the statements of Ward (1896), which seem to merit every confidence. On the map of Lake Michigan I have, however, indicated also the 40-fathom limit by a dotted line. The area between the dotted line and the black area shows the region which contains longjaws in commercial quantities, especially along its shoreward margin. The blackfins rarely enter this area, but remain in deeper water. This area is one into which the whitefish doubtless wander to a greater or less extent, but according to the statements of Professor Ward, not in commercial quantities. The map shows that if this area between the dotted line and the black area be included within the range of the true whitefish, that range is even then not con-

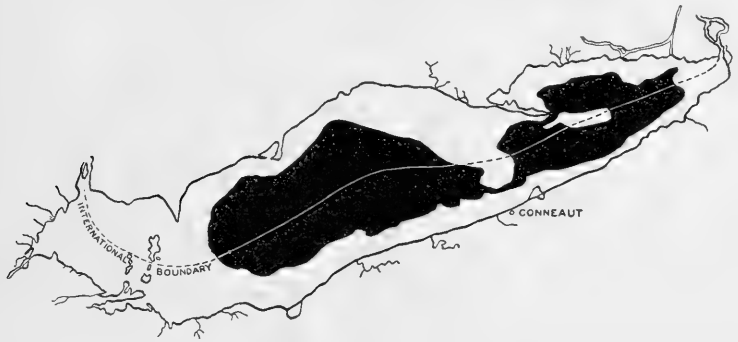

FIG. 4.—LAKE ERIE.

Whitefish area (shown in black), 12 to 30 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1477. Scale: 1 in. = about 50 miles.)

tinuous along the eastern shore of Lake Michigan. It is interrupted north of Big Point Au Sable and in a number of places still farther north. In handling the statistics of these fisheries we have attempted to study discreet areas within individual lakes. The extent of these is indicated in another place.

Within the whole whitefish area of the Great Lakes the production of marketable whitefish has greatly declined since the first statistics were taken in 1880. This is evident from a glance at the table given by Alexander (1905, p. 650), where is given the whitefish production for each lake for the years 1880, 1885, 1890, 1893, 1899, 1903. As to the cause of this decrease there is no difference of opinion among those who have investigated it. Investigators from Milner in 1871 to Rathbun and Wakeham in 1893 to 1896 have reached but one conclusion, namely, that the decrease is due to overfishing. Ward (1896)

strengthens this conclusion when he finds that on grounds where whitefish were formerly abundant, but on which they are now scarce, the food of the whitefish still exists in apparent abundance. The following quotations from Professor Ward are of interest in this connection. He says (p. 24):

> We are thus forced to the conclusion that the decrease in the whitefish supply can have no other cause than overcatching. This is not the place to discuss good and bad methods of fishing or remedies for the trouble. Our investigations point unmistakably to the cause of the depletion in the whitefish supply; it is the removal from the lakes of a larger number than can be replaced by natural processes and than has been successfully returned by artificial hatching.

FIG. 5.—LAKE ONTARIO.

Whitefish area (shown in black), 10 to 20 fathoms. (Reduced from U. S. Hydrographic Office chart no. 1477. Scale: 1 in. = about 48 miles.)

Again (p. 67) he says:

> There is a plentiful supply of whitefish food on the old fishing grounds. No reason can be assigned for the diminution in the supply of whitefish save overcatching.

I can only concur in these opinions, which are supported by incontrovertible evidence collected by many investigators.

EFFECT OF PROPAGATION UPON WHITEFISH PRODUCTION IN THE GREAT LAKES.

ANNUAL CATCH AND PLANT IN MICHIGAN AND CANADIAN WATERS.

In tables 1 to 10 are arranged certain data concerning the annual catch and annual plant of whitefish in Michigan and Canadian waters of the Great Lakes for the fifteen years 1892 to 1906, inclusive. The catch of whitefish

in Michigan has been taken directly from the original records on file in the office of the Michigan Fish Commission, while the catch in Canadian waters has been kindly furnished by the Department of Marine and Fisheries of the Dominion of Canada. The plants of whitefish that have been made in Canadian and Michigan waters have been taken from the reports of the Department of Marine and Fisheries of the Dominion of Canada, from the reports of the United States Fish Commission, and from the reports of the Michigan Fish Commission. In the column headed "Total gill and pound nets in fathoms" are given in fathoms the added lengths of gill nets and of pound-net leaders. The lengths of gill nets are given in fathoms in the official records. The lengths of pound nets are also given in fathoms in the Michigan records, but in the Canadian records the number only of pound nets is given, without their lengths. In order to obtain the lengths of pound nets used in Canadian waters I have averaged the lengths of approximately 1,000 Michigan pound nets selected at random, and have multiplied the number of Canadian pound nets in each year by this average value. In the last column of the tables 1 to 10 are given the values obtained by dividing the total catch of whitefish in pounds by the lengths of gill nets and pound nets in fathoms. The figures in this column therefore express in pounds for each year the catch of whitefish per fathom of nets used. It should be understood, however, that these tables give the total lengths of all gill and pounds nets used in the waters referred to whether the nets actually took whitefish or not. I have found it impossible to separate the nets which were set for whitefish or which took whitefish from those which were set for other fish, and I have been therefore under the necessity of taking the total lengths of all gill and pound nets used in the waters under discussion. As will appear in the discussion which follows, I attach relatively little importance to this part of the table.

I have already alluded to the difficulty encountered in obtaining statistics which deal with whitefish only and which do not include at the same time longjaws, bluefins, or menominees. We are assured by the superintendent of the Michigan Fish Commission that the data for the catch of whitefish in Michigan waters contained in tables 1 to 10 include true whitefish (*Coregonus clupeiformis*) only, and I am assured that the statistics of the catch of whitefish collected by the authorities of the Dominion of Canada and included in tables 1 to 10 refer to the true whitefish only and do not include bluefins or longjaws. These tables therefore have a peculiar interest in being, so far as I know, the only tables published of the catch of true whitefish for a continuous period of fifteen years.

TABLE 1.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE SUPERIOR FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892		1,800,640	78,820	22.84
1893		927,700	119,670	7.82
1894		1,087,733	162,650	6.68
1895		947,895	206,760	4.58
1896		850,600	189,640	4.43
1897		726,675	245,100	2.97
1898		663,230	215,380	2.61
1899	[a] 1,500,000	623,229	387,490	1.51
1900	[a] 2,000,000	461,546	224,980	2.05
1901		482,766	146,425	3.29
1902		398,943	133,450	2.98
1903		563,950	182,445	3.09
1904		430,520	237,595	1.83
1905		491,980	229,300	2.10
1906		420,700	247,400	1.70

[a] Planted by United States Fish Commission.

TABLE 2.—ANNUAL CATCH AND PLANT OF WHITEFISH, AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE SUPERIOR (EXCLUSIVE OF ISLE ROYAL) FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[a] 2,000,000 8,500,000	2,754,200	542,781	5.07
1893	[a] 11,000,000 8,000,000	2,423,600	596,220	4.06
1894	[a] 14,000,000 8,885,000	2,385,100	803,395	2.96
1895	[a] 13,350,000 28,900,000	1,618,220	705,306	2.39
1896	[a] 16,250,000 1,000,000	1,401,900	869,006	1.61
1897	[a] 8,000,000 11,990,000	1,329,284	744,809	1.78
1898	[a] 3,000,000 2,000,000	1,223,940	685,620	1.78
1899	[a] 4,000,000 5,200,000	1,128,650	724,271	1.55
1900	22,790,000	1,106,050	684,843	1.64
1901	[a] 12,800,000 20,800,000	1,056,325	911,995	1.15
1902	[a] 18,800,000 39,800,000	1,615,775	1,089,840	1.04
1903	[a] 16,600,000 13,300,000	1,345,000	1,060,990	1.26
1904	[a] 9,075,000	979,000	1,407,400	.69
1905	[a] 10,576,000 21,200,000	1,061,150	1,265,646	.83
1906	[a] 31,460,000 21,544,000	964,000	1,332,542	.72

[a] Planted by Wisconsin and United States Fish Commissions in Chequamegon Bay; adjacent to Michigan waters not included in calculations of table.

TABLE 3.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF THE NORTH SHORE OF LAKE MICHIGAN FROM WISCONSIN BORDER TO THE STRAIT OF MACKINAW FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.[a]

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	8,000,000	1,093,183	398,299	2.49
1893	8,000,000	952,050	391,682	2.43
1894	8,500,000	576,300	460,097	1.25
1895	4,000,000	461,661	295,502	1.56
1896	7,386,000	870,000	390,099	2.23
1897	19 540,000	1,346,120	553,672	2.63
1898		1,179,350	495,426	2.37
1899	6,000,000	781,080	543,710	1.43
1900	4,000,000	601,450	465,700	1.28
1901	[b] 6,000,000	799,800	539,819	1.48
1902	2,000,000 [b] 12,000,000	1,036,950	703,020	1.47
1903	11,000,000	1,131,600	778,716	1.40
1904	3 000,000	1,070,000	867,310	1.24
1905	6 000,000	1,112,700	771,617	1.44
1906	7 000,000	1,563,200	1,088,429	1.43

[a] Strait of Mackinaw not included.

[b] Planted from Mackinaw City in waters adjacent to those of the north shore.

TABLE 4.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE MICHIGAN FROM LITTLE POINT AU SABLE TO THE INDIANA BORDER FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.[a]

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	8,500,000	30,615	497,371	0.061
1893	6,000,000	47,100	600,828	.078
1894	14,500,000	88,875	424,482	.209
1895	2,000,000	50,650	368,447	.136
1896	2,000,000	39,850	390,638	.102
1897	6,000,000	32,783	237,662	.138
1898		24,150	261,736	.082
1899		27,500	306,860	.078
1900		27,850	506,921	.054
1901	[b] 4,000,000	29,350	560,291	.052
1902		26,900	624,520	.043
1903		38,400	598,690	.064
1904		69,200	691,260	.100
1905		185,200	858,691	.215
1906		337,600	832,051	.405

[a] From the United States Fish Commission Report for 1887, p. 84, we find that the catch in this area in 1885 was 538,817 pounds.

[b] At Michigan City, Ind., very near the Michigan boundary line.

TABLE 5.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE MICHIGAN FROM MANISTEE TO FRANKFORT [a] FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch in pounds per net-fathom.
1892	8 500,000	222,600	162,706	1.36
1893	6,000,000	255,000	151,090	1.02
1894	11,000,000	72,700	138,483	5.36
1895	8,000,000	78,150	150,447	.517
1896	6,000,000	109,800	181,966	.60
1897	6,500,000	145,200	80,583	1.80
1898		155,200	138,552	1.12
1899		140,750	134,490	1.04
1900	16,000,000	161,200	187,551	.86
1901		155,200	153,780	1.00
1902		261,000	195,472	1.33
1903		172,600	210,240	.82
1904		226,000	249,840	.90
1905		190,600	296,753	.63
1906		205,000	262,020	.72

[a] From United States Fish Commission Report for 1887, p. 84, we find the catch at Frankfort alone for 1885 was 885,504 pounds.

TABLE 6.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN MICHIGAN WATERS OF LAKE HURON FROM MACKINAW CITY TO PORT HURON FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	21,750,000	555,350	588,019	0.94
1893	16,640,000	535,750	528,566	1.01
1894	16,050,000	396,350	505,497	.78
1895	15,500,000	357,317	657,255	.54
1896	19,850,000	659,234	347,799	1.79
1897	23,440,000	525,860	435,345	1.20
1898	5,600,000	387,740	537,794	.72
1899	12,000,000	482,980	622,686	.77
1900	34,200,000	403,020	766,278	.52
1901	26,000,000	600,620	873,896	.68
1902	42,000,000	639,600	843,691	.77
1903	30,000,000	722,560	1,050,667	.68
1904	30,000,000	618,960	1,056,170	.58
1905	25,000,000	329,260	1,235,910	.26
1906	20,000,000	265,320	772,098	.34

TABLE 7.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE HURON, INCLUDING NORTH CHANNEL, FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.[a]

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[b] 3,000,000	2,639,156	391,067	6.74
1893	3,000,000	2,278,300	679,395	3.35
1894	3,000,000	1,504,436	741,135	2.03
1895	3,000,000	771,475	535,670	1.44
1896	3,000,000	1,091,950	598,380	1.82
1897	3,000,000	740,041	240,525	3.08
1898	3,300,000	904,180	683,480	1.32
1899	4,000,000	864,240	335,772	2.57
1900	4,000,000	1,255,075	554,045	2.26
1901	4,300,000	935,003	471,732	1.97
1902	5,000,000	1,181,268	868,137	1.36
1903	4,000,000	831,610	659,835	1.26
1904	3,000,000	1,578,790	650,630	2.42
1905	4,000,000	739,410	824,010	.89
1906	4,000,000	922,800	709,440	1.32

[a] Exclusive of Georgian Bay.

[b] In the absence of exact information for the years 1892 and 1893 the plants of these years are assumed to have been the same as in the years immediately following and are so entered here.

TABLE 8.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN THE WATERS OF GEORGIAN BAY FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom
1892		3,635,700	40,000	90.89
1893		1,601,000	773,500	2.06
1894		1,199,300	581,250	2.06
1895		642,030	1,071,000	.59
1896		584,750	620,650	.90
1897		311,995	528,300	.59
1898	600,000	340,750	653,400	.52
1899	300,000	822,520	615,071	1.33
1900	550,000	274,180	419,450	.65
1901	600,000	501,842	329,950	1.53
1902		465,590	361,030	1.28
1903		467,080	844,100	.55
1904		470,670	441,650	1.06
1905		333,620	443,550	.75
1906		379,950	486,190	.78

TABLE 9.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE ERIE FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.[a]	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[b] 34,500,000	311,950	32,850	9.49
1893	[b] 58,000,000	256,240	49,540	5.17
1894	37,000,000	153,033	73,660	2.08
1895	61,000,000	148,010	84,410	1.75
1896	49,000,000	126,300	86,990	1.44
1897	60,000,000	270,290	92,360	2.92
1898	59,000,000	245,365	90,480	2.71
1899	60,000,000	431,022	107,910	3.99
1900	64,000,000	401,425	191,915	2.09
1901	60,000,000	523,366	141,460	3.69
1902	77,000,000	449,886	133,411	3.37
1903	62,000,000	303,280	169,250	1.79
1904	44,000,000	360,800	228,535	1.57
1905	72,000,000	304,400	236,200	1.29
1906	55,000,000	359,100	268,480	1.33

[a] Includes Detroit River.

[b] In the absence of exact information for the years 1892 and 1893 the plants of these years are assumed to have been the same for Lake Huron, Georgian Bay, and Lake Ontario as in the years immediately following, and the remaining plant was assigned to Lake Erie.

TABLE 10.—ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN CANADIAN WATERS OF LAKE ONTARIO FOR EACH OF THE YEARS 1892 TO 1906, INCLUSIVE.

Years.	Plant of fry.	Catch, in pounds.	Total gill and pound nets, in fathoms.	Catch, in pounds per net-fathom.
1892	[a] 3,800,000	489,900	144,775	3.38
1893	[a] 3,800,000	369,570	126,730	2.91
1894	3,800,400	299,930	158,705	1.88
1895	4,800,000	126,650	173,045	.72
1896	4,800,000	170,350	255,100	.66
1897	4,800,000	292,460	273,670	1.06
1898	4,900,000	410,420	233,810	1.75
1899	5,050,000	259,815	168,155	1.54
1900	4,800,000	129,126	231,405	.55
1901	4,550,000	133,192	156,480	.85
1902	3,000,000	77,071	153,920	.50
1903	3,000,000	96,980	189,352	.51
1904	4,000,000	190,650	221,512	.86
1905	4,000,000	472,770	249,820	1.89
1906	4,000,000	354,000	258,792	1.37

[a] In the absence of exact information for the plants in 1892 and 1893 it has been assumed to be the same from each hatchery as in the years immediately following, the total plant remaining constant, and is so set down here.

An examination of any one of these tables shows great fluctuation in the annual catch of whitefish, which may increase or diminish nearly 50 per cent between one season and the next, and in some cases varies 300 per cent between successive years. The cause of these annual fluctuations is to be found, no doubt, in part in the weather conditions, which permit almost continuous fishing in one season while they may greatly interfere with the fishing in the succeeding season. But these fluctuations may also be due in part to some feature of the habits of the whitefish themselves which we do not at all understand. It would be possible, by terminating almost any one of these tables at a suitable point, to convey the impression that there has been a very great falling off in the catch of whitefish in any one of the lakes. Thus if table 2 should terminate with the year 1902 it would show apparently a steady decrease in the catch of whitefish in the Canadian waters of Lake Superior and a like impression may be gained with respect to any other one of the lakes by terminating the table at the appropriate year.

DISCUSSION OF AVERAGE CATCH AND PLANT FOR CERTAIN AREAS.

It is evident from an examination of tables 1 to 10 that no conclusion of value is to be reached by comparing the whitefish production of the Great Lakes for individual years. The annual fluctuations, whatever may be their cause, vitiate any conclusions that may be drawn from such comparisons. It is further evident that any comparisons should take into account the relative whitefish areas of the lakes compared, and should consider both the catch and the plant with reference to these areas.

In tables 11 to 18 an attempt has been made to avoid the errors just mentioned by comparing the average catch for the three five-year periods from 1892 to 1906, inclusive. In the first column is entered the average annual catch in pounds for each of these five-year periods. In the second column is given the average catch per square mile of whitefish area, while in the third column is stated the average catch per fathom of net used. In the same tables are given the plants of whitefish; the annual average for each five-year period, the average per square mile of whitefish area, and the average per pound of whitefish caught. The same tables give the average annual number of fathoms of nets used for each period and the fathoms of nets per square mile. By nets is to be here again understood all nets used in the areas in question, not merely nets in which whitefish were taken. Not much value can therefore be attached to that part of the table which deals with nets.

Canadian and Michigan waters of Lake Superior.—In table 11 the data for the Canadian and Michigan waters of Lake Superior are brought together for comparison. The Michigan whitefish area of 2,400 square miles extends from the St. Marys River westward to the Wisconsin boundary line, as indicated on the map of Lake Superior. It does not include Isle Royal for the reason that

this offers an isolated whitefish area unconnected with that to the north or south of it, and for the further reason that the statistical returns from this remote area show such extraordinary fluctuations in catch, plant, and amount of nets used as to make them of little value. The Canadian side of Lake Superior shows a whitefish area of 3,600 square miles, stretching from the St. Marys River westward to the Minnesota boundary. On the Michigan shore there has been a very large annual plant of whitefish fry, averaging 11,000,000 in the first period, 22,000,000 in the second period, and 15,000,000 in the third period. This amounts to about 5,000 fry planted annually per square mile of area during the first period, 9,000 during the second period, and 6,000 during the third period. For each pound of fish taken out there has been planted during the first period an annual average of 5 fry, during the second period an annual average of about 19, and during the third period an annual average of more than 12. These values would be greatly increased if they were made to include the Wisconsin plants, which are indicated by the footnote in table 2, but not included in the calculations in table 11.

TABLE 11.—COMPARISON OF THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN AND CANADIAN WATERS OF LAKE SUPERIOR FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.[a]

Michigan waters, whitefish area 2,400 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	2,117,000	881	3.22	11,057,000	4,607	5.2	703,300	293
1897–1901	1,169,000	487	1.58	21,858,000	9,178	18.8	750,300	312
1902–1906	1,193,000	497	.91	15,268,900	6,362	12.8	1,231,300	513

Canadian waters, whitefish area 3,600 square miles.

1892–1896	1,123,000	312	9.27				151,500	42
1897–1901	591,000	164	2.48	700,000	194	1.2	243,800	67
1902–1906	402,000	128	2.32				206,000	57

[a] Exclusive of Isle Royal.

If we compare the catches over this area for the three periods, we see that while there was a decline of nearly a million pounds in the annual average between the first period and the second, there was a slight increase in the third period as compared with the second. The whitefish production of this area is therefore not decreasing; it is increasing. This increase has been accompanied by a considerable increase in the length of nets used, but as will appear in another place in this paper there seems to be good reason for the belief that an increase in the length of nets used is not sufficient to account for the increase

in the catch under the conditions existing in the Great Lakes. Furthermore, we have no reason to believe that the additional nets were used for whitefish.

If we turn now to the Canadian area of Lake Superior as shown in table 11 we see that there was no plant of whitefish fry during the first and third periods and during the second period a plant averaging but 700,000 annually, 194 per square mile, or but little over one fry per pound of fish. This plant was all made at a single locality—Port Arthur—and during the two years 1899 and 1900. The catch of whitefish in this Canadian area decreased from the first to the second period in about the same proportion as the catch on the American side and it continued to decrease notably in the third period. This decrease took place on the Canadian side while an increase was in progress on the American side, and it took place in spite of the fact that the length of nets in use on the Canadian side was but from one-third to one-fifth that on the American side. During the third period the fishermen on the American side were fishing nearly ten times the length of nets per square mile that their Canadian brothers were permitted to use and were enjoying an increase in the average annual catch of whitefish while the Canadian fishermen were suffering from a decrease in the average annual catch.

Canadian and Michigan waters of Lake Huron.—The data for these waters are given in tables 12 and 13. The Michigan waters are those of the west shore of Lake Huron from Mackinaw City to Port Huron. The Canadian waters are, in table 12, the eastern shore of Lake Huron, including the North Channel, and in table 13 the Georgian Bay. We see that on the Michigan side there has been a plant of from about 18,000,000 fry annually in the first period to nearly 30,000,000 annually in the third period. This is a plant averaging from 5,500 to 9,000 fry per square mile of whitefish area. In other words, from 36 to 58 fry have been placed in these waters for every pound of whitefish taken from them. The catch of whitefish has remained practically constant, but has increased somewhat in the last period as compared to the second. On the Canadian side of Lake Huron there has been a comparatively light plant of whitefish fry in each of the three periods, less than one-sixth that on the Michigan side. The catch of whitefish fell off very much in the second period as compared with the first, but recovered somewhat during the third period. If we compare the Michigan waters of Lake Huron with Georgian Bay (Canadian) we find that in Georgian Bay there has been comparatively little planting of whitefish and this confined to the second period. It averages but 152 fry per square mile of whitefish area and but 1 fry per pound of whitefish caught. The catch of whitefish has fallen off more than two-thirds in the second period as compared with the first and has diminished still further, though slightly, in the third period.

TABLE 12.—COMPARISON OF THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN AND CANADIAN WATERS OF LAKE HURON FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

Michigan waters, whitefish area 3,200 square miles.[a]

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathoms.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	501,000	158	0.99	17,958,000	5,559	36	525,400	164
1897–1901	480,000	148	.79	20,258,000	6 271	42	847,100	264
1902–1906	515,000	159	.58	29,400,000	9,101	58	991,700	309

Canadian waters, whitefish area 3,000 square miles.[b]

1892–1896	1,657,000	552	3.07	3,000,000	1,000	1.8	589,100	196
1896–1901	940,000	313	2.24	3,720,000	1.240	3.9	457,100	150
1902–1906	1,051,000	350	1.45	4,000,000	1.333	3.8	742,500	244

[a] From Mackinaw City to Port Huron.
[b] North Channel and Lake Huron exclusive of Georgian Bay.

TABLE 13.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN GEORGIAN BAY WATERS FOR THE THREE FIVE-YEAR PERIODS 1892–1906, INCLUSIVE.

Whitefish area 2,700 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	1,535,000	568	19.3				617,300	228
1897–1901	450,000	166	.92	410,000	152	1	508,600	188
1902–1906	423,000	156	.88				515,300	191

We appear to have disclosed in Lakes Superior and Huron a relation between the plant of whitefish fry and the catch of a subsequent period of such a sort that when the plant has been considerable the catch has either been maintained or has increased, while when the plant has been small the catch has usually diminished. There are no statistics available which enable us to compare for long periods the data for the two sides of the same lake, except those for Lakes Superior and Huron, but it will be of interest to compare with these two lakes Lakes Erie and Ontario and parts of Lake Michigan.

Canadian waters of Lake Erie and Lake Ontario.—The only statistics available for continuous periods are those of the Canadian sides of these lakes, but these are of especial interest, because they enable us to compare Canadian waters in which there has been relatively heavy planting of whitefish fry with those in which the plant has been light. The Canadian whitefish areas of Lake Erie,

including both the eastern and western portions, are 2,100 square miles. For each of the five-year periods considered the plant on this area has been enormous—from about 28,000 to about 30,000 fry per square mile of whitefish area, or from 139 to 230 fry per pound of whitefish caught. At the same time the catch has increased, nearly doubling in the second period as compared with the first and then remaining practically constant during the third period.

In Lake Ontario the area of whitefish ground on the Canadian side has been estimated at 1,400 square miles. The plant per square mile has been about one-tenth that in Lake Erie, while the catch has diminished appreciably, though not greatly.

TABLE 14.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN CANADIAN WATERS OF LAKES ERIE AND ONTARIO FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

Lake Erie, whitefish area 2,100 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	199,000	94	3.98	45,900,000	21,857	230	65,500	31
1897–1901	354,000	168	3.08	60,500,000	28,857	171	124,800	59
1902–1906	355,000	169	1.87	62,000,000	29,523	175	207,200	98

Lake Ontario, whitefish area 1,400 square miles.

1892–1896	291,000	207	1.91	4,200,000	3,000	14	171,800	122
1897–1901	245,000	175	1.15	4,820,000	3,443	19	212,700	152
1902–1906	238,000	170	1.02	3,600,000	2,571	15	214,000	153

Unfortunately, we have no statistics of the catch of whitefish for the American side of either Lake Erie or Lake Ontario for any continuous period of years, so we are unable to make comparisons with the Canadian side. In table 22 there is shown the annual catch and plant in the whole of these lakes for the years 1899 and 1903, the only years for which statistics are available for the catch in which the true whitefish is separated from related forms in American waters.

The statistics of the catch need not detain us here, but those of the plant are interesting since they show that for the first of these years the total plant in Lake Erie from all sources, Canadian and American, was about 197,000,000 fry, while the plant in Lake Ontario for the same year was less than one-tenth as great. In 1903 the plant in Lake Erie was still nearly four times that in Lake Ontario. Not only is there this very great difference in the plant in these two lakes, a difference which exists in other years also, but it is extremely probable that the Lake Erie plant on the American side affects the catch on the Canadian side. The whitefish area of Lake Erie is practically continuous for the eastern

part of the lake and continuous in a nearly separate area for the western part of the lake. Any plants therefore on either side of the lake might well produce fish that would make their way to the opposite shore. In interpreting table 14 it is therefore to be taken into account that the plant affecting the Canadian catch is probably much greater than that entered in the table and would probably be more correctly represented by values similar to those entered in table 18. On the other hand, both the actual and the effective plants in Lake Ontario are very much less than in Lake Erie. We see thus in the Canadian waters of Lake Erie a very great increase in the production of whitefish correlated with very large plants of fry. In Lake Ontario we see a reduction in whitefish production correlated with a moderate plant of fry, a plant which is, for unit area, about half that of the Michigan waters of Lake Superior for the same periods.

Restricted areas of Lake Michigan.—In tables 15 and 16 there are brought together the data of catch, plant, and nets used in certain restricted areas of Lake Michigan. The data for the catch are all taken from the records of the Michigan Fish Commission, while those of the plant are published in the reports of the Michigan Fish Commission and the United States Bureau of Fisheries.

The areas selected are as follows:

(1) An area designated in table 15 as the "north shore" of Lake Michigan comprises the whitefish grounds from the Strait of Mackinaw westward to the Michigan-Wisconsin boundary in Lake Michigan. The eastern limit of this area is therefore well defined, but at its western limit it is broadly continuous with the waters of the State of Wisconsin. It contains 800 square miles, as shown on the map of Lake Michigan. The plant of whitefish fry in this area in the three successive five-year periods has been from 7,000 to 9,000 per square mile and from 5 to 9 per pound of fish caught. At the same time the catch in round numbers has been, in successive periods, 800,000, 950,000, 1,200,000. Here we have again a greatly increased catch correlated with a large and intensive plant.

(2) An area designated in the table as the "southeast" Michigan shore, comprises the whitefish grounds from Little Point Au Sable south to the Indiana-Michigan boundary. At its northern limit this area is nearly separated from the whitefish area to the north of it, but at its southern end it is broadly continuous with the Indiana waters of Lake Michigan. These waters, have, however, for a long time yielded very few whitefish, so that the area in question may be regarded as practically limited by barren waters at its lower end. Its area is 300 square miles. For the first period this area received a plant of 22,000 fry annually per square mile, an average of 125 per pound of fish caught. In the second period the plant was reduced to an average of about 7,000 annually, or 68 per pound of fish caught. The latter averages are based on a total which includes a plant of 4,000,000 made in 1901 at Michigan City, Ind., just beyond the Michigan border. If this plant be excluded the figures for the second period are reduced 40 per cent. Here again we have a very large increase in the catch

correlated with a very large and intensive plant. The catch of the third period exceeds that of the second more than fivefold. The number of whitefish appears, however, not to have increased in the period immediately following the greatest activity in planting, for while the plant of the first period was very great the catch of the succeeding period showed a decrease to little more than one-half that of the preceding period. This is possibly to be explained by the fact that in the nineties this area was considered to be nearly depleted of whitefish, and fishing for them was prosecuted with much less vigor than before. The number of fathoms of nets in use fell off, and it is probable that the nets set for whitefish fell off still more. It seems, therefore, probable that the whitefish may have begun to increase during the second period, but that this fact was not known to the fishermen until well into the third period. In other words, it is probable that the catch did not increase until some years after the whitefish themselves had increased. A glance at table 4 shows that this increase in the catch became noticeable in 1903.

TABLE 15.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN WATERS OF LAKE MICHIGAN (THE NORTH SHORE AND THE SOUTHEAST SHORE) FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

North shore, whitefish area 800 square miles.[a]

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	791,000	988	1.99	7,177,000	8,971	9	387,100	459
1897–1901	942,000	1,177	1.83	5,908,000	7,385	6	519,600	649
1902–1906	1,183,000	1,477	1.39	5,800,000	7,250	5	841,800	1,052

Southeast Michigan shore, whitefish area 300 square miles.[b]

1892–1896	52,000	170	0.117	6,600,000	22,000	125	456,300	1,521
1897–1901	29,000	96	.081	2,000,000	6,666	68	374,700	1,249
1902–1906	132,000	440	.165				721,000	2,403

[a] North shore, from the Wisconsin border to the Strait of Mackinaw (excluding the Strait of Mackinaw).
[b] Southeast shore, from Little Point Au Sable south to the Indiana border.

(3) The Manistee-Frankfort area is an apparently isolated area of 90 square miles lying off the cities of those names. The data for this area are shown in table 16 (for annual data see table 5). Here we have a plant of fry which for the area is enormous, nearly 90,000 per square mile in the first period and nearly 60,000 per square mile during the second period. There was no plant during the third period. The catch has risen during the fifteen years from 128,000 pounds per square mile in the first period to 152,000 in the second and 211,000 in the third. Here again we have a correlation of heavy planting with increased yield of fish.

TABLE 16.—SHOWING THE AVERAGE CATCHES AND PLANTS OF WHITEFISH IN MICHIGAN WATERS OF LAKE MICHIGAN FROM MANISTEE TO FRANKFORT, INCLUSIVE, FOR THE THREE FIVE-YEAR PERIODS 1892 TO 1906, INCLUSIVE.

Whitefish area, 90 square miles.

Years.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1892–1896	128,000	1,422	0.80	7,900,000	87,777	62	156,900	1,743
1897–1901	152,000	1,688	1.16	5,300,000	58,888	35	138,900	1,543
1902–1906	211,000	2,344	.88				242,900	2,498

PRODUCTION COMPARED WITH INTENSITY OF PLANT.

The data that have been presented seem to show that wherever, whether in American or Canadian waters, there has been a large plant of whitefish fry per unit area (20,000 in at least one period) this is correlated with a considerably increased average yield of adult fish per unit area in one or another period (Manistee and Frankfort and southeast Michigan areas of Lake Michigan, Canadian waters of Lake Erie); wherever there has been a moderate plant of fry per unit area (5,000 to 10,000 per square mile) this is correlated with a moderately increased yield of adult fish per unit area in one or another period or by a practically stationary yield (north shore of Lake Michigan, Michigan waters of Lake Huron from Port Huron to Mackinaw City, Michigan waters of Lake Superior); wherever there has been a small plant of whitefish fry per unit area (less than about 3,500) or no plant, this is correlated with a diminished yield of adult fish per unit area (Canadian waters of Lakes Superior, Ontario, and Huron and Georgian Bay, except for a slight increase in Lake Huron from second to third period).

CONCLUSIONS AS TO EFFECT OF PROPAGATION.

The result reached in this section is expressed in another form in tables 17 and 17*a*, in which the whitefish areas already discussed are arranged in the order of the intensity of the plant made on them per unit area. Arranged in this way the series falls into three groups. The first, including the Manistee and Frankfort area, the southeast Michigan shore, and the Canadian waters of Lake Erie, comprises areas which have in at least one of the three periods received plants of at least 20,000 per square mile. The increase or decrease in the catch of each area of this group is shown for the second and third periods in the right-hand column in percentages of the catch compared with that of the preceding period. Positive values indicate an increase in catch, negative values a decrease. These percentages are of considerable amount and are positive in every case but one; the catch for the southeast Michigan shore is less for the second period than for the first (43 per cent), but it increases again enormously in passing from the second period to the third (350 per cent).

The second group of areas as arranged in table 17 includes the north shore of Lake Michigan, the west shore of Lake Huron from Mackinaw City to Port Huron, and the south shore (Michigan waters) of Lake Superior. In this group the intensity of the plant of whitefish fry per square mile varies from about 5,000 to about 10,000. But two negative percentages appear in the table opposite these areas; these are both in passing from the first to the second period, and both are reversed in passing from the second to the third period, where they become positive.

The third group of areas includes the north shore of Lake Ontario, the east or Canadian shore of Lake Huron, the north shore of Lake Superior, and Georgian Bay. The plant per unit area has been largest in Lake Ontario, but has not there exceeded 3,600 per square mile. It diminishes progressively in the order in which the areas are named above, and becomes practically nothing in Lake Superior and Georgian Bay. The percentage column shows no positive value, while the sum of the negative values is very large.

TABLE 17.—SHOWING THE RELATIONSHIP OF THE AVERAGE PLANT OF WHITEFISH FRY PER UNIT AREA IN CERTAIN WATERS OF THE GREAT LAKES, TO THE AVERAGE CATCH IN THE SAME UNIT AREA FOR THREE FIVE-YEAR PERIODS.

	Whitefish areas.	Plant per square mile (to nearest 100).	Catch, pounds, per square mile (to nearest 10).	Per cent of increase (plus values) or decrease (minus values) of each period over the preceding period.
	1892–1896.			
1	Manistee and Frankfort	87,800	1,420	
	Lake Erie (Canadian)	21,900	94	
	Lake Michigan (southeast shore)	22,000	170	
	Lake Michigan (north shore)	9,000	990	
2	Lake Huron (west shore)	5,600	160	
	Lake Superior (south shore)	4,600	880	
	Lake Ontario (north shore)	3,000	210	
	Lake Huron (east shore)	1,000	550	
3	Lake Superior (north shore)		310	
	Georgian Bay		570	
	1897–1901.			
1	Manistee and Frankfort	58,900	1,690	+ 18
	Lake Erie (Canadian)	28,900	168	+ 78
	Lake Michigan (southeast shore)	6,700	96	− 43
	Lake Michigan (north shore)	7,300	1,200	+ 21
2	Lake Huron (west shore)	6,300	148	− 6
	Lake Superior (south shore)	9,200	490	− 44
	Lake Ontario (north shore)	3,500	175	− 16
	Lake Huron (east shore)	1,200	310	− 43
3	Lake Superior (north shore)	194	164	− 47
	Georgian Bay	152	166	− 70
	1902–1906.			
1	Manistee and Frankfort		2,344	+ 28
	Lake Erie (Canadian)	29,523	169	+ .5
	Lake Michigan (southeast shore)		440	+350
	Lake Michigan (north shore)	7,300	1,500	+ 25
2	Lake Huron (west shore)	9,100	160	+ 6
	Lake Superior (south shore)	6,400	500	+ 2
	Lake Ontario (north shore)	2,600	170	− 2
	Lake Huron (east shore)	1,300	350	− 1
3	Lake Superior (north shore)		128	− 22
	Georgian Bay		156	− 6

TABLE 17*a*.—SHOWING THE RELATION BETWEEN THE AVERAGE PLANT OF WHITEFISH FRY PER SQUARE MILE PER PERIOD AND PER POUND CAUGHT PER PERIOD TO THE AVERAGE PERCENTAGE OF INCREASE OR DECREASE IN THE CATCH OF EACH PERIOD OVER THE PRECEDING PERIOD.

	Whitefish areas.	Average plant per square mile per area for five-year periods.	Average plant per pound caught per area for five-year periods.	Average percentage of increase (+) or decrease (−) of period 2 (1897–1901) over period 1 (1892–1896) and of period 3 over period 2.
1	Manistee and Frankfort Lake Erie (Canadian) Lake Michigan (southeast shore)	28,000	96	[a]+72.0
2	Lake Michigan (north shore) Lake Huron (west shore) Lake Superior (south shore) Lake Ontario (north shore)	10,000	32	+ 0.7
3	Lake Huron (east shore) Lake Superior (north Shore) Georgian Bay	2,200	11	−26.0

[a] If we exclude Lake Michigan, southeast shore, on account of the phenomenal increase of 350 per cent in the third period, this value becomes +31, but there appears to be no valid reason for such exclusion.

In table 17*a* is shown the relation of the average intensity of plant of each of the three groups of areas to the average catch in the same areas. The first column contains the average of the plant for the areas of each group for the three periods expressed in fry per square mile and the second column contains a like average expressed in fry per pound of whitefish caught. Thus the value 28,000 in the first column of table 17*a* is obtained by adding all the numbers in the first column of table 17 opposite the areas of the first group and dividing the sum by 9, and the remaining values in columns one and two of table 17*a* are obtained in like manner. The percentages in the third column of table 17*a* are obtained by adding for each group of areas the percentages given in the third column of table 17 and dividing by 6 in the case of groups 1 and 2 and by 8 in the case of group 3.

It thus appears that, on the average, a plant of approximately 30,000 per square mile of whitefish area or of 100 per pound of whitefish caught is correlated, under existing conditions, with an increase of 72 per cent in the catch; a plant of 10,000 and 32 with a practically stationary whitefish product; a plant of 2,200 and 11 with a decrease of 26 per cent in the whitefish product. This appears to the writer to amount to a mathematical demonstration of the efficacy of the planting of whitefish and to afford a measure of the intensity of plant necessary. This measure applies, of course, to present conditions; as the whitefish production increases it is possible that a plant of less than 100 per pound will suffice to maintain the fisheries.

In table 22 is given the total plant and catch for the Great Lakes and from this appears the average intensity of plant for 1903, the last year for which data are available for the catch. The intensity of the plant per pound caught is here

shown to be approximately 50. It appears therefore that the plant should be annually at least twice what it was in 1903. If the writer remembers correctly the cost of producing whitefish fry has been in the recent experience of the United States Bureau of Fisheries about two cents per 1,000 in Michigan. At this rate the cost of planting per pound of fish caught would be about 2 mills.

This correlation of an increased output of whitefish with a large intensive plant of fry and of a reduced production of whitefish or a stationary product with a small or diffuse plant of fry holds good in waters which are fished under the same restrictive legislative enactments. The Canadian waters of Lake Erie fall at one end of the above series, while the Canadian waters of Lake Superior fall at the other end of the series. These waters are fished under the same laws, dominion and provincial. The differences in their output can not therefore be referred to differences in legislative control. The Manistee-Frankfort area and the Michigan southeast-shore area are fished under American nonrestrictive enactments, while the Canadian waters of Lake Erie are fished under the restrictive laws already referred to, and yet both, having received large and intensive plants of whitefish fry, have yielded increased returns in spite of differences in the fishing regulations.

The writer is forced to conclude that the increased production of whitefish in certain areas of the Great Lakes for the averages of five-year periods is due not to legislative enactment, but to the liberal and intensive planting of fry.

EFFECT OF LEGISLATIVE ENACTMENT ON WHITEFISH PRODUCTION.

An analysis of the fisheries regulations of the Dominion of Canada, the Province of Ontario, and the State of Michigan, under which the fisheries were carried on, the data of which are presented in this paper, can not be here undertaken. An act of the Michigan legislature of 1897 provides that, with certain minor exceptions, "it shall be unlawful for any person to fish with any kind of net whatever in the waters of this State from the thirtieth day of October to the fifteenth day of December." The fisheries regulations of the Dominion of Canada provide a close season for whitefish from November 1 to November 30, inclusive, in the Province of Ontario, but certain waters of Lake Erie and the Detroit River and Lake St. Clair are excepted by recent enactment. So far as the close season is concerned the Michigan and Canadian regulations are in essential agreement. They both aim to protect the whitefish during the spawning season. It is quite possible that the improvement in the whitefish fisheries in Michigan waters in recent years, as shown in the tables in this paper, is in part due to the close season which has been in force for about half of the period covered by these tables. That the improvement is not due wholly to the close season is clear when we remember that the Canadian whitefish catch has declined in many regions where a close season is enforced. The close season as

it now is limited is therefore not in itself sufficient to bring about an improvement of the fishery for whitefish.

Under the regulations of the Dominion of Canada fisheries officers are empowered to regulate the distances between nets, and if the writer understands these regulations, the fishing grounds are leased and the fishermen licensed. The result of this system is that a much smaller number of nets, or a much shorter total length of nets, is in use in the Canadian waters of the Great Lakes than in the American waters. In tables 18 and 19 are shown the data for the plant and catch of whitefish for the Canadian and American waters of Lakes Erie and Ontario for the only years for which American statistics are available in which it is possible to discriminate the true whitefish from related forms. From these it appears that the total length of gill and pound nets in use in the American waters of Lake Erie was in 1893 about twenty times that in use in Canadian waters, although the Canadian and American waters have approximately the same area. The Canadian nets in that year took about four times as many pounds of fish per fathom of length as the American nets. In 1899 the American nets are still of about twenty times the length in total of the Canadian nets, which are taking between four and five times the weight of fish per fathom. In 1903 the American nets still exceed the Canadian more than ten times, and the Canadian are taking more than ten times the weight of fish per fathom. In this year the weight of whitefish taken in the waters of the two countries is the same. An examination of tables 11 and 12 shows that in Lakes Superior and Huron the American nets exceed the Canadian in total length and the Canadian nets exceed the American in catch per net fathom. The latter statement is true only if we assume that the whitefish are taken in the waters of both countries in the same proportion to other fish.

TABLE 18.—COMPARISON OF THE ANNUAL CATCHES AND PLANTS OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN UNITED STATES AND CANADIAN WATERS OF LAKE ERIE FOR THE THREE YEARS 1893, 1899, 1903.

Canada, north shore, whitefish area 2,100 square miles.

Year.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1893	256,000	121	5.17	58,000,000	27,619	226	49,500	23
1899	431,000	205	3.99	60,000,000	28,571	139	107,900	51
1903	303,000	144	1.79	62,000,000	29,523	204	169,300	80

United States, south shore, whitefish area 2,000 square miles.

1893	1,292,000	646	1.3	22,570,000	11,285	18	988,900	485
1899	2,066,000	1,033	.88	104,930,000	52,465	50	2,325,200	1,164
1903	303,000	152	.16	90,961,000	45,480	30	1,816,300	908

TABLE 19.—COMPARISON OF THE ANNUAL CATCH AND PLANTS OF WHITEFISH AND TOTAL LENGTH OF NETS IN USE IN UNITED STATES AND CANADIAN WATERS OF LAKE ONTARIO FOR THE YEARS 1899 AND 1903.

Canadian waters, whitefish area 1,400 square miles.

Year.	Catch.			Plant.			Nets.	
	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1899	259,000	185	1.5	5,050,000	3,607	19	168,200	120
1903	97,000	69	.52	3,000,000	2,142	30	186,400	133

United States waters, whitefish area 800 square miles.

1899	161,900	202	2.0	13,475,000	16,847	83	79,700	99
1903	25,400	32	.22	43,920,000	54,900	1,729	114,400	143

It seems clear to the writer that limitation of the length of the nets in use has not resulted in an improvement of the whitefish production. The whitefish catch in Canadian waters of Lake Erie has diminished and again increased (see table 9), although the length of nets has remained but a fraction of that on the American side of the same lake. The same thing has happened on the American side of the lake, if we may judge by the only available statistics, those of the State of Pennsylvania, which are given in table 21.

In table 20 are shown the lengths of nets used in American and Canadian waters of Lake Erie, as compared to the total catch of all fish in the same waters. From this it appears that when all fish are considered the Canadian nets took in 1899 about four times as many pounds of fish per fathom as the American nets, while in 1903 they took about three times as many pounds.

TABLE 20.—COMPARING IN ROUND NUMBERS THE TOTAL LENGTH OF GILL AND POUND NETS AND THE CATCH OF ALL FISH IN CANADIAN AND AMERICAN WATERS OF LAKE ERIE FOR THE YEARS 1899 AND 1903.

Year.	Canadian waters.			American waters.		
	Nets.	Catch.	Catch per net-fathom.	Nets.	Catch.	Catch per net-fathom.
	Fathoms.	*Pounds.*	*Pounds.*	*Fathoms.*	*Pounds.*	*Pounds.*
1899	107,900	10,063,000	93	2,325,200	58,394,000	25
1903	169,300	5,409,000	32	1,816,300	23,189,000	12

TABLE 21.—SHOWING IN POUNDS THE ANNUAL CATCH OF WHITEFISH IN THE PENNSYLVANIA WATERS OF LAKE ERIE FOR THE YEARS 1892–1906, INCLUSIVE; FROM THE RECORDS OF THE PENNSYLVANIA FISHERY COMMISSION.

Year.	Pounds.	Year.	Pounds.
1892	15,000,000	1900 and 1901	57,840,000
1893	19,800,000	1902	44,560,000
1894	25,000,000	1903	19,836,000
1895	42,000,000	1904	39,200,000
1896	30,000,000	1905	34,489,000
1897	41,000,000	1906	36,468,000
1898 and 1899	32,000,000		

TABLE 22.—SHOWING THE ANNUAL CATCH AND PLANT OF WHITEFISH AND TOTAL LENGTH OF NETS USED IN THE GREAT LAKES, EXCLUSIVE OF LAKE ST. CLAIR, FOR THE YEARS 1899 AND 1903.

Lake Michigan, whitefish area 2,600 square miles.

Year.	Total pounds.	Pounds per square mile.	Pounds per net-fathom.	Total fry.	Fry per square mile.	Fry per pound caught.	Total fathoms.	Fathoms per square mile.
1899	1,510,000	503	.58	53,500,000	20,577	35	2,605,600	1,002
1903	1,973,000	682	.77	6,000,000	7,307	3	2,564,400	986

Lake Huron and North Channel, whitefish area 9,300 square miles.

1899	1,457,000	158	1.9	24,000,000	2,580	16	756,500	81
1903	1,525,000	163	2.3	39,000,000	4,193	25	649,600	69

Lake Superior, whitefish area 7,500 square miles.

1899	1,316,000	175	1.7	16,700,000	2,226	12	736,600	98
1903	1,358,000	180	1.9	32,000,000	4,266	24	721,400	96

Lake Erie, whitefish area 4,100 square miles.

1899	2,497,000	609	1.0	196,930,000	48,031	78	2,433,000	593
1903	606,000	147	.30	152,961,000	37,307	252	1,985,000	484

Lake Ontario, whitefish area 2,200 square miles.

1899	422,000	191	1.7	18,725,000	8,511	44	247,800	111
1903	122,000	55	.40	41,000,000	18,636	336	300,800	136

All Great Lakes,[a] whitefish area 25,700 square miles.

1899	7,202,000	280	1.0	309,855,000	12,056	43	6,779,500	263
1903	5,584,000	217	.89	270,961,000	10,543	49	6,221,200	242

[a] Exclusive of Lake St. Clair.

Total length of nets in use seems, therefore, not to have affected the total catch of whitefish. The explanation of this apparent contradiction is probably as follows, although this explanation is offered with much reserve: When fishing is begun in a virgin water, the catch depends necessarily on the amount of apparatus in use. As the rate of catch per unit of apparatus diminishes, which it invariably does, there comes a time when it ceases to be profitable to multiply the amount of apparatus, and as a consequence the number of units of apparatus ceases to grow. The relation of the amount of apparatus to the catch per unit of apparatus is, where no restrictions exist, a self-regulating one. The apparatus is sure to increase to the point where its use barely affords a profit to the user. The total apparatus is not in the water because required in order to catch the total amount of fish actually taken; it is there rather because each fisherman hopes to take the fish which would otherwise fall to another. If, now, the amount of apparatus be diminished, the same number of fish will still be taken in the diminished number of nets until the rate at which they are caught falls below the natural rate of increase of the fish, when, of course, the total catch of fish will increase. If these considerations are well grounded, the regulation of the number or length of nets per unit area does not act to preserve the fisheries unless that regulation proceeds to an extreme that it is not likely to reach in practice. So far as the preservation of the fisheries is concerned, the regulation of the length of nets to be used on unit area may well be left to competition, provided competition is in some way insured. These remarks do not apply, however, to regulation of the length or location of those nets which might impede the movements of fish during the spawning season; they assume, rather, that the spawning season is a close season.

To reduce the length of nets per unit area is, however, advantageous in another way, since it tends to lessen the cost of taking the fish and should make it possible to furnish them to the public at a less price. If fishing grounds are leased in such a way as to insure competition among lessees and to prevent the leases falling into the hands of a single lessee, and if the length of nets permitted on unit area is then restricted, the fish should come to the market at a lower price, for each fisherman would be compelled to take the fish at a less cost to himself and competition would compel him to market them at a less cost. This principle is commonly applied in another way by the licensing of hunters and sport fishermen and the limitation of the catch that they are permitted to take. Here, where pecuniary profit is not an inducement to increase the catch, it is not regulated by the cost of getting it. The sport fisherman tends to get all he can no matter at what cost, and hence it is necessary to regulate the size of his catch by law in order to prevent his exhausting the supply of fish. In commercial fishing exhaustion does not take place, because it is not profitable and it is necessary to regulate the apparatus used only in order to

lessen the cost of fishing. The conclusion reached in this section is that neither the close season nor regulation of the amount of apparatus is in itself sufficient to increase the output of the whitefish fisheries of the Great Lakes. The close season is presumably of assistance and should be preserved, since it protects the fish when they may be most readily taken in large numbers. The regulation of the length of apparatus to be employed in the whitefish fisheries has not resulted in preserving the fisheries, but is presumably advantageous in lessening the cost of operation, since it increases the number of pounds of fish taken per unit of net without reducing the total catch.

SUMMARY OF CONCLUSIONS.

1. The possible modes of increasing the production of whitefish in the Great Lakes are discussed and the conclusion reached that under existing conditions there are but two modes available, planting of whitefish fry and restrictive legislation. The problem is then stated to be a statistical one, that of determining by the study of existing statistical data the effect on the whitefish catch of the lakes of the planting of whitefish fry and of various forms of restrictive legislation. It is shown that it is necessary to have statistics for a continuous period of years for true whitefish only both for plant and catch and under various legislative restrictions. The necessity of discussing average catches with reference to unit areas of fishing ground is insisted on. Finally, it is shown that the necessary statistics are to be found only in the records of the Michigan Fish Commission and in those of the Department of Marine and Fisheries of the Dominion of Canada.

2. The habits of the whitefish are discussed, with the conclusion that the fish is a bottom feeder, restricted in its range during nine months of the year to waters of very definite depth. The depths assigned by investigators to the whitefish are then tabulated for each of the Great Lakes, the areas showing these depths are charted, and the extent of these areas measured in square miles. The whitefish areas as thus defined are then briefly described for each lake and it is shown that they are not in all cases continuous areas. Evidence is then adduced to show that the whitefish are local in their habits, so that each part of each area supports its own group of fish, which are in large measure confined to the area, leaving it only in fall when going inshore to spawn and in spring or summer for about two months.

3. In studying the relation of the plant of whitefish fry to the catch it is found that in those lakes or parts of lakes where there has been a large and intensive plant of whitefish fry (30,000 per square mile) there has been a correlated increase in the catch of whitefish (72 per cent); in those lakes or parts of lakes in which there has been a moderate plant of whitefish fry (10,000 per square mile) there has been a slight increase in the catch of whitefish or the

catch has remained nearly constant; in those lakes or parts of lakes in which there has been a small plant of whitefish fry (2,000 per square mile) or no plant, there has been a reduction in the catch of whitefish (26 per cent). (Certain exceptions to this statement are also noted.) It is shown that under Canadian restrictive legislation the whitefish have diminished in waters where planting of fry has been at a minimum and have increased in waters where planting has been liberal; that whitefish have increased in American waters where there has been no restrictive legislation (or little) and have diminished in Canadian waters of the same lake under restrictive legislation. These increases and decreases are stated to be, therefore, in relation to the plant of whitefish fry and not to legislative control.

4. Discussion of the effect of legislation on whitefish production leads to the conclusion that (*a*) a close season during the breeding period is probably advantageous to the production of whitefish, although the data at hand do not furnish any evidence on that score, and (*b*) that a practicable regulation of the number of nets or the length of nets to be used in unit area of the lake does not increase the production of whitefish, but does tend to greater economy in the fishing, since the same number of pounds of fish are taken with fewer nets.

MEASURES RECOMMENDED AS MEANS OF INCREASING WHITEFISH PRODUCTION IN THE GREAT LAKES.

1. It is recommended, as a result of the foregoing study, that the output of whitefish fry be increased as rapidly as possible, as affording the most certain means of increasing the whitefish production.

2. That an intensive plant of at least 100 fry per pound of whitefish caught be made on depleted areas. (Lake Ontario and the southern waters of Lake Michigan are in need of especial attention.)

3. That a close season be observed during the breeding season of the whitefish as at present, but only for such waters as are not under federal control (see sec. 4, below).

4. That commercial fishing with pound nets and seines be permitted in the waters of the Great Lakes during the breeding season of the whitefish wherever the state or national authorities are prepared to undertake to care for the spawn of the fish taken; the fishermen to be under legal obligation to permit the use of the fish taken by them for the purpose of spawntaking.

5. It is suggested that central control of the fishing operations of the Great Lakes is highly desirable. Whether this is possible in American waters through federal control or through concerted action of the states is a question that can not be discussed here. A central control, under which fishing grounds should be leased and fishermen licensed, would, if properly administered, reduce the cost of fishing and make possible more extended

artificial propagation. The central authorities should have power to modify the fishing regulations pending legislative action. Such a system might be made self-supporting.

6. The need of more exact knowledge of the habits of the whitefish and of all the conditions under which it lives is very evident. In the interest of the fisheries these matters should be subjects of investigations to be carried on under federal auspices, with suitable equipment and for a long period of years.

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DISCUSSION.

Prof. EDWARD E. PRINCE. I do not wish to usurp the time of the congress unduly, but I will say a word or two about the opinions expressed in the two or three papers this morning on the question of whitefish production in the Great Lakes. It is a matter which is of very, very great importance to us in Canada—in fact, I may say I am chairman of a commission appointed by the Dominion government which has the protection of the whitefish, especially of Lakes Huron and Erie, before it. I give the writers of the papers this morning credit for wishing to do something practical in the matter of preserving the whitefish. I give them credit for that. At the same time I, as Canadian commissioner of fisheries and having a good deal to do with administration of fishery laws, see difficulties in the suggestions which were made in the papers this morning, and especially I see this difficulty, that the prohibition of the capture of small whitefish, so long as pound nets or fish traps are allowed, is almost an impossibility—that is to say, the prevention of their destruction. You may try as you will to prevent the taking of small whitefish, but they will be taken. You may prohibit their sale, but they will be handled and in some way disposed of. Therefore the question comes to this: If you adopt a policy which will be extremely difficult or impossible to carry out, it is better to pause before adopting that policy. If you adopt a closed season—and we in Canada, have always favored closed seasons, and have to some extent carried them out (I say that, in justice to our official staff with which I am connected, we have tried to carry out the closed season in Canada)—if you adopt a closed season, which prevents any nets whatever being used and removes all nets from the water, that is an effective measure. You can do that. You can protect the fish by preventing the capture altogether—that is, by taking the nets out of the water for, say, the month of November.

I know that Mr. Clark and others will claim that hatcheries will make up for everything in the way of destruction of fish by nets if you also preserve the immature fish; and one of the strong points in favor of artificial hatching of fish (instead of allowing parent fish during a closed season to spawn) is that great loss arises from nonfertilization of eggs. I think that is a point which is open to discussion, and I will give you an illustration, and then I shall sit down. Sometime ago I was engaged in hatching sea fish, and I hatched about 70 different species; and I tried on more than one occasion to keep some eggs in the laboratory tanks free from fertilization. The sperms which the male shed in the open sea would reach those eggs through the supply pipes wherever they were placed. In other words, it was almost impossible to keep them unfertilized after they were taken from the ripe female. I investigated the same thing in sockeye salmon in British Columbia. I tried on the spawning beds to get eggs which were not fertilized. I went into the water knee-deep to get them and groped about on the spawning beds there, where the fish were engaged in spawning; and I tell you, gentlemen, I have gathered quantities of natural fish spawn on the beds, and I failed, in some thousands of eggs, to get one single egg that was not fertilized, which showed how scrupulously nature accomplishes the fertilization of eggs under natural conditions. At the same time, I do not deny that eggs may escape impregnation, yet, so far as my observations go, the eggs which were deposited by the parent fish are almost to an egg fertilized.

I do not wish to say more, Mr. President, but merely these few words.

The PRESIDENT. The next gentleman.

Mr. C. H. Wilson. I desire, as the representative of the State of New York, to congratulate the gentlemen who have furnished these most interesting papers upon this question. I wish to back it up by the protective element and the department of fisheries of the State of New York. While we give you great credit for what you have done, for what you, in your enthusiasm, hope to do, yet we do not believe the time is ripe when we should sever a partnership with nature and the Almighty. [Laughter.]

The first paper speaks of the effect of pollution of the waters of the Great Lakes upon the spawning beds of the whitefish. If the beds of the whitefish are destroyed by the thousands of acres, as stated in this paper, I submit to you, Mr. President and gentlemen of this congress, that the time has not arrived when we shall fail to take advantage of everything to conserve the food fishes of North America.

An argument is made in this paper regarding the closed season. The writer wishes to close the season for two months, that the commercial fishermen under the guise of gathering spawn for the hatcheries may rush in and slaughter by the thousands the whitefish of the Great Lakes. May I ask you, gentlemen, what risk do you run in having a closed season during the spawning period of the whitefish? By an open season you do invite the continuance of an illicit business already begun in the taking of whitefish eggs for caviare, one seizure of one and one-half barrels of eggs in transit having been made last year. You establish a precedent that will later plague you regarding other varieties of fish.

The enthusiasm of the writer of one of these papers sees the Great Lakes overcrowded with fish; the sober judgment of another says, "We may never expect to return to former conditions;" while the third, uncertain of his position, says, "A closed season may be advantageous." The showing of the enthusiastic and faithful operators of hatcheries is fine and gratifying to all; but the catch, after all, determines the real pounds pressure of their enthusiasm. Successful planting must follow successful hatching, and protection wait upon both; and the argument of all arguments in these papers is the statement that the propagation and protection show increase in the last few years. What protection? Practically all states and provinces bordering on the Great Lakes, save the state of Pennsylvania, with its 45 miles of shore line, have in recent years given protection by a closed season during the spawning time of this valuable fish.

The statement is made that a closed season will interfere with the taking of spawn. Mr. Chester K. Green, who operates a hatchery at Cape Vincent, N. Y., will tell you that the state of New York, which I represent on this floor, has given to the United States Government permission to take all the spawn it wishes for hatchery purposes.

Hon. Paul North. Representing the state fish and game commission of Ohio, I would state that the question of preserving the whitefish on Lake Erie is a very difficult one, owing to the fact that Lake Erie has four states and the Dominion of Canada bordering, and each and every state has a different law, to a great extent, governing the taking and catching of these fish. It is a notorious fact that up until the last year New York State permitted the fishing with gill nets of 2½-inch mesh, and tons of immature fish were caught at Dunkirk and those points—immature whitefish that were of absolutely no use whatever—in the summer when they are soft and no good. Of course there comes the question that if you stop the catching of fish there you will stop the commercial fishermen of New York from making a certain living. And if we, as a general government of Canada and the United States, regulate this and have a closed season until such a time as the fish come up the lake, why, then, the Ohio fishermen get all the benefit; and you can see where the trouble is going to come in and what a difficult matter it is to handle. But the main thing, in my mind, is that Mr. Clark and Mr. Downing are both absolutely right in their premises that one hatchery will produce more whitefish than all the whitefish in a natural state produce.

You must remember that as the whitefish have decreased the means of taking them have increased. The mileage of the gill nets has increased, and the pound nets have increased, until now in places you will see 30 in one string reaching out into the lake, and it is a wonder that any fish have been left. We should have regulation all along the line—the size, number of pounds they can have in one string of nets; and there must be a regulation, gentlemen, that every whitefish that is taken with spawn must, as far as possible, be put in the hatchery; and if we can have 50 hatcheries on Lake Erie there is no question but what we can have a very large increase in the quantity of that fish, as shown by the effect of the 2 hatcheries on the lakes, which have in the last five or six years increased the catch until last year we had the biggest catch on Lake Erie we have had in the last fifteen years; all due to those 2 hatcheries. Nature has been doing as much as she could; but those 2 hatcheries have done the work. Mr. Downing and Mr. Clark know what they are talking about; they know what the conditions are; they know that the hatcheries will do the work; and that if you can by this means conserve every whitefish until you get its spawn and then run that spawn through a hatchery you will have all the whitefish in Lake Erie and more than it ever had before. [Applause.]

Mr. KELLY EVANS. I should just like to take up my three minutes by calling attention to a point in one of the papers that was read this morning, in which the statement was made that while we had a closed season on the Canadian side of the Great Lakes the fish in our waters were not as plentiful as they were in the waters on your side of the lakes, at several points. I would remind one or two of the fishery commissioners present that they have already spoken to me at different periods of time in reference to using nets by arranging with the Canadian authorities to allow them to gather eggs on the Canadian side of the lakes. Does it not seem curious to you that if the fish are to be found in very much larger quantities on their side they should wish to come to our side for eggs? That is one point I wish to make.

The second point I wish to make is this, that if the condition outlined in the splendid papers read this morning is practically possible to bring about, you will have reached undoubtedly a Utopian condition; but on our side of the water, at any rate, I feel convinced that that Utopian condition of things will require a great many years to reach. In consequence, if this congress came out very strongly as supporting the general proposition that hatcheries could be depended upon entirely, and that nature might be ignored, it might result disastrously on our side of the water. If at any point in our international waters all the spawn-bearing fish can be so taken care of that their spawn is in no way lost, possibly the proposition of depending upon the hatcheries alone is the best one; but until that condition of things has been brought about it is a very dangerous thing to say to great nature, "We need your assistance no longer." I therefore, from these points of view, urge the congress to go very slowly on this question of abandoning great Dame Nature. [Applause.]

Dr. BARTON W. EVERMANN. Mr. President, I would like to discuss this question, but I think I shall refrain. I would like to ask one question, however, which I think can be answered by Superintendent Lambson, of the California station. If I have been correctly informed, the natural spawning beds of the Sacramento salmon in the Sacramento River basin have been practically wiped out of existence through mining and other operations of that kind, so that even if no salmon were caught in the Sacramento River either for commercial or for hatchery purposes and all salmon in that stream were allowed to ascend to such spawning beds as they might find they would probably amount to nothing; they would be unable to find any suitable spawning beds, because those beds have been destroyed. But through artificial propagation in the Sacramento basin I understand that the catch of salmon in that river now is very large. Some years it is larger than it was ever known to be before artificial propagation began and before

that river was so much changed physically because of the results of mining and agricultural operations. If those are the facts, it seems to me that they point a very important question and suggest very strongly the wisdom of the course which has been recommended by two or three gentlemen in the papers they have presented. It appears to me that we should no more depend upon natural reproduction in any of the species of fish that we can handle than we should depend upon natural reproduction of corn or potatoes or any other thing that may be left to the wild. [Applause.]

Dr. TARLETON H. BEAN (New York). Just a word, Mr. President and gentlemen of the congress, merely to remind you of the present condition of the shad fisheries of the United States, which, it appears to me, is one of the very best illustrations of what can be done by artificial culture as against natural reproduction in streams that have been more or less polluted. I shall go not very far south of the Hudson River and the Delaware for my illustration, and say the Potomac. You gentlemen know as well as I that to-day the fisheries—the commercial fisheries of those rivers, especially the shad fisheries—rest absolutely on an artificial basis; and they have so rested for the past quarter of a century. It is within my knowledge and within your knowledge that in 1874 shad were selling in the Washington markets at 75 cents apiece on the average. You know what they are worth to-day, and you know why it is that you can buy them to-day for one-third the price that you paid in 1874. I will not enlarge upon this topic, but merely remind you that the Hudson, the Delaware, and the Potomac for the past quarter of a century have been increasingly polluted. The natural spawning beds or grounds have been covered with cinders and other waste products of industries; and without artificial propagation there would be no such thing as a run of shad in the North River or the Hudson River to-day, as there has been in 1907 and 1908, equaling the catch of more than twenty years ago.

Mr. FRYER. I do not gather that all the spawning grounds of all the whitefish in the Great Lakes are polluted; neither do I gather that they are spoiled by refuse from timber works, sawmills, or from any other such cause.

Mr. FRANK N. CLARK. If I understand you correctly, you do not understand that the spawning grounds of the whitefish are polluted. They most certainly are. In my paper I speak of the Thunder Bay River region, where the beds are polluted out 9 miles in a bay that is 30 miles across, and there are no whitefish in that territory where they used to spawn in great numbers.

Mr. FRYER. If that applies equally to all the spawning grounds of the whitefish in the Great Lakes, then, of course, my point falls.

Mr. CLARK. It does not apply to all.

Mr. FRYER. Then the point I wished to make is that, assuming there are natural spawning beds still left in the Great Lakes——

Mr. CLARK [interrupting]. Oh, yes.

Mr. FRYER [continuing]. I am glad the assumption is correct for the sake of the fisheries themselves. My argument is this: There is a great distinction to be drawn between the case of the Great Lake fisheries and the cases that have been referred to, such as the shad fisheries of the Hudson and elsewhere, where it is found that all the spawning beds are either polluted or are so cut off from the fish as to be practically unavailable, and I expect that in the paper that is about to follow, on the fisheries of the Rhine, you will find information given which will enforce the point that there is a great distinction to be drawn between those cases where nature still has a little room left to perform its own functions and the cases where the natural conditions have been practically destroyed; and, on the premise that there are still natural spawning beds available for the whitefish, I would venture to support the view put forward by Professor Prince, that you have great cause for hesitation before you put aside the question of improving or endeavoring to improve these fisheries by restrictive measures and rely

solely upon the measures proposed in those three very excellent and admirable papers which were read this morning, the sincerity of whose authors one can not fail to appreciate and admire, however one may differ from their conclusions.

Professor Prince referred to the difficulty of regulating the sale of undersized fish. In England it has been found—as has been recorded in very quaint language in some old statutes—that although the law prohibited the sale of small fish their capture was inevitable; and when such methods of capture as hooks and lines were employed, and the small fish had to be thrown back into the sea, they were destroyed, and the public were thus deprived of a certain supply of fish. This is another illustration of the difficulty referred to by Professor Prince.

At the present moment we have in Europe a difficulty in connection with certain grounds on the southeastern part of the North Sea, where very large quantities of what are known as immature or undersized plaice are caught, with very few adults. The suggestion was therefore made in that case that an international regulation might be passed which would prevent the sale of fish under a certain size, the idea being that although the prevention of sale would not in itself prevent the capture, yet the proportion of small fish taken on those grounds is so large that if the sale were prohibited it would not be worth the while of the fishermen to fish there any longer, and so, indirectly, under those circumstances, the prohibition of sale would have the same effect as the prohibition of capture. A period of one hundred and eighty seconds is not very long to deal with such an important question as this, but I would like to enforce one point made in the last paper, namely, that our knowledge with regard to the spawning of fish is not as perfect as it ought to be. On the mere point of fertilization of the ova, a very simple test would settle the question as to the proportion of the ova fertilized naturally. I may, incidentally, indorse Professor Prince's experience in the matter of salmon eggs. I have myself collected salmon and trout ova fertilized naturally, under normal conditions, and I have not found 5 per cent of the eggs unfertilized, so that, prima facie, there seems very great reason to doubt that the proportion of unfertilized eggs in the case of the whitefish can possibly be 99 per cent, as suggested.

If I might intrude one minute longer, I would throw out the suggestion—I do it with great diffidence, because I do not know all the local details, but as a very broad proposition for consideration—that it might be possible to arrange between the United States of America and the Dominion of Canada for the waters of the Great Lakes to be treated as a common fishery, common to the two countries, subject to common laws, equally enforced on both sides, and based on the most perfect knowledge that it is possible to obtain with regard to the habits of fish, and of course with regard to the habits of man, as to which I personally, as I said before, have insufficient knowledge. I just make the suggestion for consideration, with the addendum that if such an idea were accepted it might be possible to arrange that the fishermen who are interested in conducting these fisheries should themselves contribute to the expense of the administration and regulation of the fisheries in these waters. Whether that administration were limited to regulations only or whether it included artificial culture does not matter. This might be done by means of a system of tolls leviable not merely by licenses to the fishermen, giving them the right to fish, but on the quantity of fish which they brought ashore, no matter where they landed it, so long as it was taken in the Great Lakes.

I make the suggestion with very great diffidence, but if it were possible to elaborate it I could give you several reasons in support of it.

Mr. J. W. Titcomb. I will answer the question raised by Professor Evermann about the run of salmon in the Sacramento River. Practically all of the salmon which ascend the river by the canneries are caught at the Bureau's hatchery and stripped of their eggs. Occasionally, say once in three or four years, with a very high freshet, the fish get by, or a part of them get by. The fish in the Sacramento River have

increased steadily for the past ten or fifteen years. The proportion of eggs which the Bureau is able to collect to-day, as compared with that of ten or fifteen years ago, is several hundred per cent greater. The observations of Captain Lambson as to the natural fertilization of the salmon show that about 75 per cent are fertilized under natural conditions; but further observations show that of the 75 per cent which are naturally fertilized fully 95 per cent are smothered in the sand, so that eventually only a few hatch. Under artificial conditions we fertilize from 90 to 95 per cent; we hatch and develop as fry from 90 to 95 per cent of eggs fertilized. The fishery there is dependent entirely on artificial propagation, and during the last ten or fifteen years has steadily increased.

In the shad fishery, which Doctor Bean has alluded to, take, for instance, the Potomac River: After the Fish Commission began its work of artificial propagation the commercial fishery came up steadily until the figures for a great many years were perfectly wonderful. We can not show that tremendous fishery to-day, for the reason that the fish are not allowed to ascend the river where we can get their eggs. All our work in the propagation of shad must be done during the spawning season, and the collection of eggs is dependent on the run of shad during that season. They can not be caught at other seasons of the year because they are not there.

I think that both the salmon and shad are an illustration of the whitefish question, to show that the open season is desirable, if we can have along with it all the necessary hatcheries and spawntakers to conserve the eggs which would otherwise go to waste. [Applause.]

Mr. W. E. Meehan. Mr. President and gentlemen, I did not intend to take part in this discussion, for the reason that it occurred to me that the papers read this morning cover the question so completely and are so fully in accord with the experiences I have had in the fisheries of Lake Erie and the Delaware River in the case of shad, whitefish, herring, and other fishes that are caught in the commercial nets for market purposes. It seems to me that the maintenance of fish by artificial propagation is necessary—that the latter is necessary to maintain fisheries. The plea that, although we may believe a closed season for non-nest-building fishes is not needed because fish hatcheries can better keep up the supply of fish than natural propagation, we ought not publicly to say so for fear some harm will be done to some other country which does not propagate is, to my mind, much like the warning which the man gave another not to teach his children to read for fear they would later on come to read pernicious literature.

All experiments made have shown that artificial propagation is necessary for the maintenance of fish in the water; that with increased population and increased demand it is impossible to maintain a supply by natural propagation. Artificial propagation has increased the supply of whitefish in Lake Erie and probably in the other lakes; it has increased the herring; it has increased the shad in the rivers. Without artificial means we would have no shad to-day. Artificial propagation has made the whitefish industry once more profitable. The best policy, in my estimation, is that which is outlined by Messrs. Downing, Clark, and Reighard, to give the freest possible fishing for whitefish, herring, and the like during the summer months when the water is warm, when the fish are soft, and when the runs of fish are apt to be small and immature as to size. Catch the large fish and give the small fish a chance to grow. If closed seasons were made during the spawning period, there is scarcely a fish-cultural station on the Great Lakes that would be filled, unless the government and the states had about every boat employed in fishing. In the state of Pennsylvania, for the hatcheries set apart particularly for the propagation of the lake fishes, it will require every boat going out of the port of Erie to fill those hatcheries, and it is doubtful even then if the houses would be full. The more fish that are hatched, the greater must be the percentage of increase in suitable waters.

These are my reasons for supporting and believing the papers of this morning as enunciating the true doctrine of increasing the food-fish supply. [Applause.]

Mr. SEYMOUR BOWER (Michigan). Mr. President and gentlemen, I had not intended to take any part in this discussion. I will say, however, that for many years I have been in hearty accord with the views regarding whitefish propagation as expressed in the papers just read. In fact, I think Mr. Clark, Mr. Stranahan, and others here will bear me out in saying that I was one of the pioneers in advancing those views. To me this proposition seems so simple as to be hardly worth a moment's consideration if we are right as to the value of what is known as artificial propagation. As evidence of its value I can state that the catch of whitefish in Michigan waters of the Great Lakes is steadily increasing, has been for a number of years, and is now very nearly double what it was ten years ago. To be more exact, in the latter part of the nineties the annual catch was a little over 3,000,000 pounds on an average, while in 1906, the last year for which we have complete statistics, the catch was over 5,000,000 pounds. The figures for 1907 and 1908 are not compiled, but our agent who is now in the field is of the opinion that both years will show a still further increase.

There is just one thought in connection with this matter which I desire to present. There are two great divisions in the forces of nature, which we might term destructive and constructive. The existence and development of all forms of life are possible only through the destruction of some other form, either animal or vegetable Now, as fish spawn in nature, the ova are subject not only to the constructive forces of their environment, but also to many destructive ones; but when transferred from that environment to an artificial or protected one, they are separated from these destructive forces and are then subject only to those that are constructive, with the result that production is increased many fold. If that proposition is true, and we have most convincing evidence that it is, the situation is greatly simplified. We should apply this principle wherever practicable; should take advantage of every opportunity to prevent the ova of the better class of food fishes from being thrown into contact with the destructive forces of nature. This is the vital point or principle in fish culture.

The PRESIDENT. Professor Birge, have you something to say in this matter? We would like to know your views.

Prof. E. A. BIRGE. I have no right to speak with any authority on this subject. I have been in agreement with the views expressed in the papers which were read this morning, but I have no such personal knowledge of whitefish culture or the whitefish industry as those gentlemen who have spoken on the subject.

Mr. W. T. THOMPSON (Colorado). I would like to say a few words along the line of thought advanced by Professor Evermann. I believe I can bring evidence from Colorado which will place the result attained by hatchery methods beyond question. Mr. Titcomb stated in his lecture this morning that larger collections of eggs from wild brook trout could be made in Colorado than in any other section. I wish to call your attention to the fact that this species is not indigenous to our state, but was first introduced about twenty-five years ago. No trout were found in the state at that time except the native species, chief among which was the blackspotted trout (*Salmo clarkii*).

The brook trout was first introduced, in small numbers, about 1882 or 1883. Some two years later the introduction of the rainbow trout was commenced in a very limited way. Coloradoans had been accustomed to the native trout for years; the waters were thickly populated with them when the white man first arrived. Naturally, they thought they would always have them without effort on their part, consequently there was no demand on the hatcheries for them; hence, we produced none. The adult fish were allowed to deposit their spawn naturally, "according to the dictates of their conscience," as we might say. I might add that the spawning beds were not polluted to any extent and were and are still accessible.

Now, let us see what has been the result in Colorado after a period of twenty-five years: Our hatcheries, beginning with these first small plants made from eggs secured from other points, gradually began to secure both brook and rainbow spawn in increasing numbers from our own waters. The Gunnison River is one of our typical trout streams. Twenty-five years ago it was full of the native trout. None were taken from it for spawning purposes, consequently it can not be claimed that the hatcheries interfered in any way with their natural reproduction. The hatcheries, meanwhile, have been industriously collecting both brook and rainbow eggs, planting the resulting fry in public waters in increasing numbers, year by year. To-day, after twenty-five years of this policy of noninterference with the natives, this species has become practically extinct in the Gunnison River, and the condition in this river is typical of what has transpired in our other streams. This same Gunnison River is still celebrated for its trout, but the reputation rests entirely on the introduced species, the hatchery products, the rainbow of the Pacific slope and the brook trout of the east, which in our Colorado waters found a congenial home and attained a higher degree of excellence than in their native habitat. Sixty-five per cent, possibly more, of the trout in the Gunnison to-day are rainbows, the balance are brooks, with an occasional native, but the latter are very rare.

So far as Colorado is concerned, both of these varieties are entirely the product of the hatcheries. Nature, or, more properly speaking, the natural method of spawning, had practically nothing to do with this remarkable increase. That this is a fact is amply attested by the rapid decrease among the natives when left to propagate naturally. Through the work of the hatcheries, our streams are still well stocked, but with the brook and rainbow trout.

Mr. Titcomb spoke of a lake containing an island, around which the fish circulated in great numbers during the spawning period. If we allowed these fish to spawn according to nature, there is no doubt but that lake would continue to be thickly populated, but it would not benefit other waters. Operated under fish-cultural methods, assisting nature in her efforts, we have taken over 6,000,000 eggs from this island lake. We could have taken more had we proper facilities at the time. With the fry from these eggs, we were enabled to stock many of the lakes and streams of the state. I believe no better illustrations can be given of the value of fish-cultural methods than we can bring you from Colorado.

Mr. Frank N. Clark. Mr. President and gentlemen, I have very little information to add in the short time allotted to me in this discussion, but I shall try to answer the two or three points which are all I am willing to concede have been made on the other side of this question.

One question, I think possibly from Mr. Fryer, or some other member, in reference to the small fish—speaking of certain nets or grounds where it was almost impossible to get along without catching small fish. Remember what I said: "Prevent any sort of fishing in certain localities where large numbers of immature fish congregate upon the feeding grounds, this legislation to pertain to all portions of the Great Lakes system where the presence of such fish has been established and to be enforced during such month or months as they make their appearance in large numbers for feeding purposes." We do not propose to permit any fishing there at all; wherever the small fish are caught in large numbers should be a government reservation—that is my idea. That is all I have to say about the small fish.

Another gentleman, I think Professor Prince, spoke of the high percentage of impregnation of the fish eggs in a natural way. With the salmon there is no doubt of it; but with trout, i. e., lake trout, not the stream trout, and with the whitefish, I thought it was conceded by all who are interested in fish culture that the percentage of impregnation of the naturally spawned fish was very low. I have always supposed it was conceded. If I might be permitted to state, Mr. President, I think it is of record in some

of our early United States Fish Commission reports, where I personally made certain observations upon this phase of our subject, and I have always supposed that this was why we approved the dry method of impregnation instead of the wet method. Experiments made by me many years ago in taking eggs of the whitefish brought me to these conclusions: You take your eggs in a pan of water with the milt, and you get a fair impregnation; you take your eggs in a pail of water, say 10 gallons, and you get a medium impregnation—perhaps 20, 30, or possibly 40 per cent. If you take your eggs in a barrel of water you may get 15 or 20 per cent. Therefore I have always concluded that where the female whitefish spawned indiscriminately in the water, with the milt no doubt added in the same way, only partial fertilization would result. In fact I believe, Mr. President, that many female whitefish spawn when there is not a male fish anywhere in the vicinity. From that we must, it seems to me, draw the conclusion that where the whitefish spawn naturally it is not possible to have any high percentage of impregnation. Personally, I do not like the word "artificial." There is nothing under the sun artificial about the care or hatching of fish eggs, excepting that you give them care. It is "protected propagation," Mr. President, and I like to use that term. There is nothing artificial in taking the eggs. You merely bring the eggs and the milt together. That is all there is of it; and then you care for them, and the care and attention which is given them in our hatcheries is what I prefer to call protected propagation.

Some speaker mentioned pound nets. Here is the ground that I take. As you will see, I make the penalty very severe to the fishermen; it is the most severe punishment that was ever thought of, in my judgment. Think of it! The third violation stops his fishing. I do not care if he is but 20 years old, he stops fishing the balance of his life. Suppose some of our immensely wealthy fishermen on the Great Lakes—take the A. Booth Packing Company—violate this law the third time, what happens? They must stop fishing or the revenue boat will attend to them.

All this is contained in this paper, and my idea is based on the idea of federal control, not state regulation. I mean federal control by the Dominion of Canada and the United States; not state control or provincial control. Our warden boats go there, and they may find a man violating the law. He is arrested; his license is taken away from him for six months; for the second offense for a longer period.

Might I be permitted to state what I said to a fisherman on the lake? I gave him my idea of this federal control, and what I proposed. I said: "You do not obey these state laws very well?" "Oh, no;" he replied, "we take our chances on getting caught." "You caught a considerable number of fish here one fall out of season?" He replied: "Yes; oh, yes." "Well," I said, "John, I know how many you caught—about $10,000 worth." He answered: "Yes; and I was taken over here and fined $500, but I had $9,500 left." I said to him: "John, what will you do if you are licensed and you violate that law, and have to stop fishing six months?" "Why," he said, "it would almost ruin me for six months." I said: "What will you do if you have to stop for a year?" He replied: "I could not stand it." That is my idea. I do not know whether I have answered all questions or not.

Mr. J. J. STRANAHAN (Georgia). Mr. Clark, you have a better memory than mine, I know. You remember what we published with reference to the fertilization of whitefish eggs on the Detroit River?

Mr. CLARK. Oh, yes.

Mr. STRANAHAN. What was the percentage?

Mr. CLARK. It was very low. I do not know that I can give the exact figures. It might have been one-half of 1 per cent.

Mr. STRANAHAN. Less than 1 in 1,000.

Mr. CLARK. Very low, indeed.

Mr. STRANAHAN. I want to speak only a word. Under the direction of the United States Commissioner of Fisheries, I was instructed to make dredgings on the reefs with

our steamer, using the hose. We did so for several days the latter part of November and the early part of December. We had an inch hose and a rotary pump; and we took up only a few thousand eggs. I can not give you the percentage, but it was somewhere in the vicinity of one egg out of three or four hundred, and, as I remember it now, we got only eleven or twelve impregnated eggs during our two or three days' work. Our work was off North Bass Island, and around the island near the hatchery where I was then superintendent.

Professor PRINCE. There is just one error that I think Mr. Clark would willingly consent to having removed, and that is that spawning grounds in the Great Lakes are all polluted. On the Canadian side there are splendid spawning beds which are unpolluted. There are great spawning grounds in Lake Erie and Georgian Bay unpolluted, and the benefit of these spawning grounds must be felt on the Great Lakes, as the benefit of the hatcheries is also felt. I wish to say that I am as strong an advocate as anybody for artificial culture, and have said so in numerous official reports; but I also think that if you can combine that work with a closed season, then you have an ideal state of things.

Mr. SAMUEL F. FULLERTON (Minnesota). Mr. President and gentlemen of the congress, have you taken into consideration that men whom I claim to be the foremost in the United States to day in their profession have written papers, all in different directions and all coming to the same conclusion? If any of your family were sick and there were a horse doctor and a physician of high standing in the same community, which would you employ—the horse doctor? No, you would take the physician of high standing. Here is Mr. Clark, who has been in the business for forty years, and Mr. Downing has perhaps been in it as long—men whose word is law in regard to fish culture; and we should take their word, not that of the horse doctor. Now, in our state last year we had a law suit; and I think this will illustrate the point I want to make as well as anything else. At that law suit we had the evidence of eleven fish culturists—the foremost men we could get. We went all over the United States for them; and the conclusion they all reached was the same: That not one whitefish or pike perch egg in 500 ever came to maturity. They were sworn men; they had made tests. I have been at it eighteen years, and I have taken eggs off the bottom rocks and off the sand and brought them to our hatchery and hatched them; but I never got 1 per cent of fry. [Applause].

Mr. DWIGHT LYDELL (Michigan). I have been listening very attentively to the speakers, and did not intend to say anything; but when some of them stated that we could get along without Dame Nature, I desire to say that I think we can not. I think all fish culturists are willing to admit that Dame Nature is what we need up to a certain point, when they step in and beat Dame Nature where the whitefish are concerned for the next five months.

I took some dredgings on the Detroit River, under the instructions of the Michigan Fish Commission, several years ago, when they were engaged in the propagation of the whitefish; and out of two quarts that I gathered nearly every day with a dredge, I failed to find any impregnated whitefish eggs. This work was carried on during the months of March and April. No whitefish eggs were collected whatever that were good, although we got quarts and pails of poor ones. That was on the natural spawning grounds.

I do not think that we ought to compare our brook trout or any of our other species of fish, except the lake herring and wall-eyed pike, with our whitefish. The whitefish spawns promiscuously in the water wherever it happens to be. The brook trout clean off their beds in the streams and spawn on them; both the male and the female are there. Take the whitefish run on the Detroit River. The female whitefish come up there in great numbers after the male run has nearly passed by. The first run comprises nearly all males; in the second run you will get ten females where you will get one male. As they are all ready to spawn, I think it would be impossible for one male to attend to so many females; but if the males that are caught from the first run are

held in crates by the fish culturist, and used when the females come on, nearly every egg is saved to be turned loose later as a lively young fish. Our tally sheets which are on file in the Fish Commissioner's office show these statements to be true. So I do not think we ought to compare the brook trout with the whitefish in this discussion at all.

Mr. FRYER. I would like to ask one question, which is, What was the condition of the whitefish fisheries of the Great Lakes say sixty years ago, before there were many of the mischiefs that exist now, such as pollutions and pound nets and other wickednesses on the part of man, and when also there was no such thing as protected reproduction?

One other question on the point of the illustration given us from Colorado. I am in doubt whether the speaker from that State wishes us to infer that the native trout had died out because there was no protected reproduction in its case, or whether we are to assume that it had succumbed to the superior numbers and greater voracity of the alien fish imported into its water.

Mr. PAUL NORTH (Ohio). I do not go back sixty years, but Mr. Fryer would know the difference in conditions on Lake Erie now as compared with sixty years ago if he could realize that we have in Lake Erie on the American side a fleet of nearly 300 tugs with 6 to 8 miles of gill nets to the tug. He could appreciate that, if the same conditions which existed sixty years ago with regard to replenishing the lake were present to-day, we would not have a fish of that kind in Lake Erie.

The PRESIDENT. Now, in regard to the question about the native trout. Mr. Thompson will reply to that question.

Mr. THOMPSON. I intended my hearers to infer that it was owing to lack of artificial propagation that the native trout had died out to so great an extent. I will state that we have in recent years commenced an extensive work with the natives, with the intention of again making them a factor in our streams. The lake Mr. Titcomb mentioned this morning, where the fish circulate around the island in countless thousands, is one of our native trout-spawning fields. It is about 200 acres in extent and has yielded over 6,000,000 eggs in a single season, this quantity being limited merely by our existing facilities.

[The discussion of the whitefish question terminated at this point but was briefly taken up again on the following day.]

The PRESIDENT. Mr. Fullerton has just spoken to me about a matter of general misunderstanding in regard to the whitefish question, and it seems to me to be of sufficient importance to be brought again before the attention of the congress. I will ask him kindly to make that statement made to me a moment ago.

Mr. FULLERTON (Minnesota). A misunderstanding has arisen in regard to the open season of whitefish, that we had the discussion on yesterday. I have talked with several gentlemen who did not understand the position that we took in regard to letting the fishermen fish in the closed season.

We did not for a moment contemplate letting any fishermen fish in the open season, except it be under the jurisdiction and under the control of the state or federal authorities, both of Canada and of the United States. I hope this explanation will clear away a misunderstanding that existed, that the fishermen are allowed to go to the spawning beds and fish at will. That is not at all intended; that would not be tolerated for a moment. They must do their fishing and taking of the eggs only under the control of the authorities.

The PRESIDENT. The chair requests, then, that those who are here will explain to any members who are interested in this problem that this explanation has been made, because I can see how it is perfectly clear to those who are connected with our national hatcheries in the United States. It is so clear, indeed, that they did not emphasize it in the discussion yesterday afternoon.